VOL. XVIII. 1910

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AMERICAN ELECTROCHEMICAL SOCIETY.

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TRANSACTIONS

OF THE

AMERICAN ELECTROCHEMICAL SOCIETY

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VOLUME XVIII.

EIGHTEENTH GENERAL MEETING

CHICAGO, ILL., OCTOBER 13, 14, 15, 1910.

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1910

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ERRATUM.

In Volume XIV, p. 218, formula (4), change the two numerators "l" to the numerals "1." The error was typographical only, and does not affect the rest of the paper.

VOLUME XVIII. 1910.

TRANSACTIONS

OF THE

AMERICAN ELECTROCHEMICAL SOCIETY

PROCEEDINGS

CONDENSED MINUTES OF THE EIGHTEENTH GENERAL MEETING OF THE SOCIETY, HELD IN CHICAGO, ILL., OCTOBER 13-15, 1910.

(Number of members registered, 112; guests, 114; total, 226.)

SESSION OF OCTOBER 13th.

The morning session was called to order at 10 o'clock, in the Florentine Room of the Congress Hotel, President Wm. H. Walker in the Chair.

Papers by Carl Hering, F. T. Snyder, R. S. Wile, E. Weintraub (read by A. B. Marvin) and Jos. W. Richards were presented and discussed, as printed in full in these Transactions.

In the afternoon, visits were arranged to the Fish Street power house (a 120,000 kw. plant, consisting of ten 12,000 kw. generators driven by Curtis steam turbines), the Market Street transformer and storage battery station of the Commonwealth Edison Company, the telephone and instrument works of the Western Electric Company, the factory of the Automatic Electric Company (where 1,300 persons are employed in the manufacture of automatic telephones), the Union Stock Yards and packing

plant of Swift and Company and Armour and Company, and the offices of the Hoskins Manufacturing Company (where a demonstration installation of various types of laboratory electric furnaces and pyrometers was shown in operation). Instructive exhibits were also shown at the Congress Hotel: Pyrometers by the Taylor Instrument Companies, of Rochester, N. Y.; a new metallurgical microscope by E. Leitz, of New York and Chicago.

During this day the ladies in attendance spent the morning at Hull House (Jane Addams' social settlement), visited the Juvenile Court and Mark White Square and, after luncheon at Hull House, joined the gentlemen in visiting the stock yards and packing plants.

SESSION OF OCTOBER 14th.

The session was called to order at 9 A. M., in the Florentine Room of the Congress Hotel, President Wm. H. Walker in the Chair.

Papers by W. S. Andrews, A. R. Johnson, F. C. Frary with H. R. Bicknell and C. A. Tronson (presented by Mr. Frary), A. R. Johnson, R. D. Small, Pedro G. Salom, O. W. Brown and W. G. Bowers (presented in abstract by Carl Hering), and Carl Hambuechen were presented and discussed, as printed in full in these Transactions.

During the sitting, a flashlight photograph was taken, which is reproduced as the frontispiece of this volume.

In the afternoon, excursions were arranged to the works of the Illinois Steel Company, at South Chicago; the Gary Steel Works, at Gary, Indiana, and to the mail order establishment of Sears, Roebuck and Company and the principal exchange of the Chicago Telephone Company.

The South Chicago Works, covering some 350 acres of ground, employs 10,000 men, and has its own water works, fire and police department, transportation system and hospital. There are 19 miles of narrow gauge and 144 miles of standard gauge tracks in the works. The pumping station furnishes 140,000,000 gallons daily, against 80 feet head. Power is developed by steam high and low-pressure turbines and gas engines. Seven boiler houses generate 50,000 boiler horse-power. In one year the plant has handled 3,483,000 tons of iron ore, and produced as follows:

1,371,771	tons	of	pig iron.
962,191	"	"	Bessemer steel.
759,259	"	"	open-hearth steel.
764,053	"	"	rails.
395,568	"	"	blooms.
278,869	"	"	slabs.
160,083	"	"	plates.
177,614	"	"	structural steel.

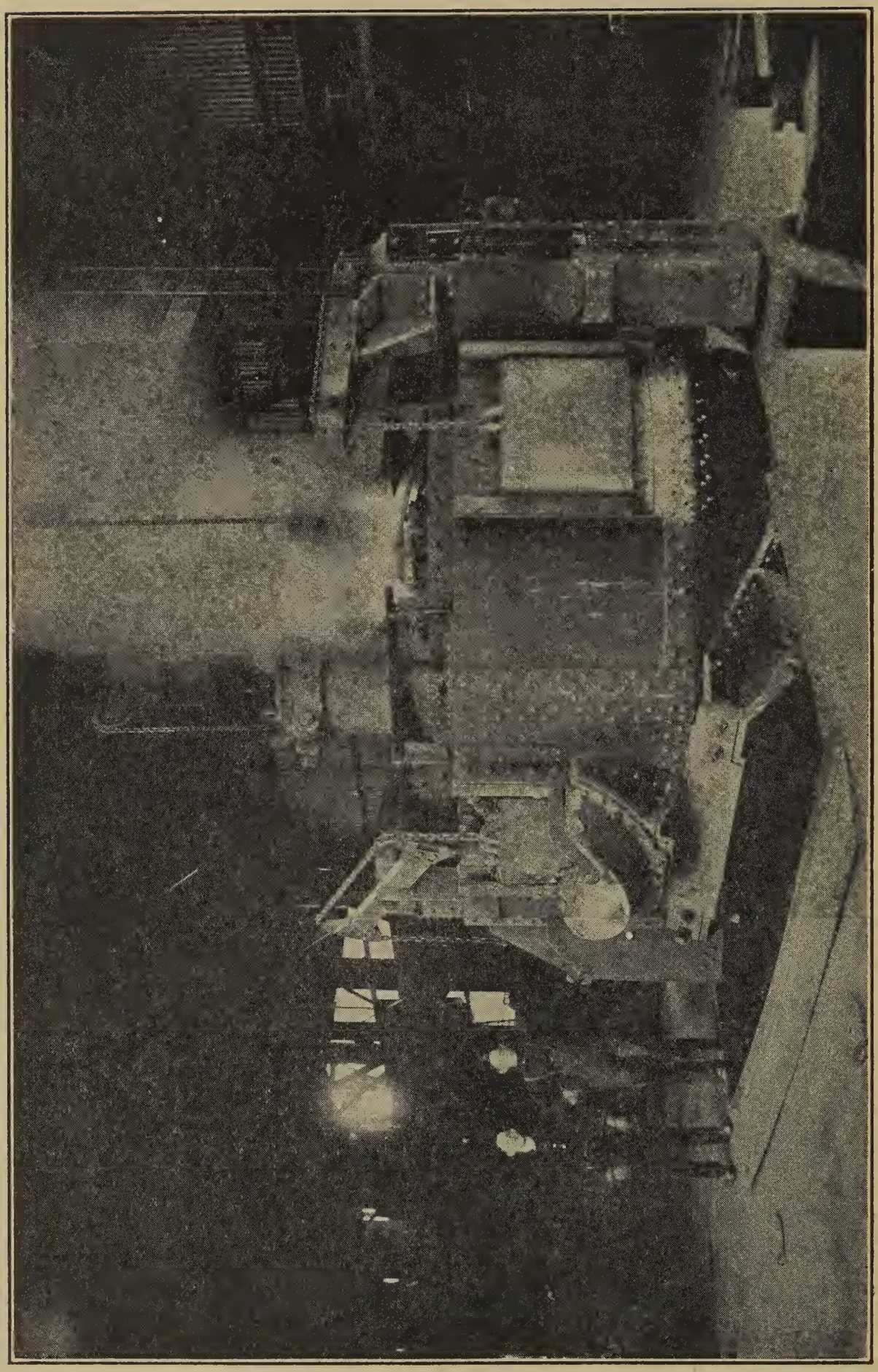
The equipment comprises 11 blast furnaces, a Gayley dry air blast plant, Bessemer plant with 3 converters, 15-ton Héroult electric furnace, 24 open-hearth furnaces, electrically driven rail and universal plate mills, and gas engine plant running on blast furnace gas.

The 15-ton electric furnace was the greatest attraction, and was seen in operation, receiving blown steel from the Bessemer converters and treating it by refining for one and one-half hours for axle steel. A photograph of this furnace as seen in operation is given here.

The Gary Steel Works is the world's largest and most modern steel works. Its description is outside of the permissible space limits. It is rumored that the United States Steel Corporation having acquired possession of the Héroult United States electric furnace patents, it is possible that a large number of large electric furnaces may be erected at Gary, instead of one of the contemplated new open-hearth plants.

During this day the ladies visited Marshall Field's store, the Art Institute, took luncheon at Sears, Roebuck and Co's, and inspected their establishment.

In the evening an informal subscription dinner, *en famille,* was held in the Florentine Room of the Congress Hotel. Mr. H. B. Coho called upon several for after-dinner speeches, among them our guest for the evening, Mr. Harry McCormack, chairman of the Chicago Sanitary District. Mr. E. A. Sperry, chairman of the New York Section of the Society, took the opportunity to extend to the Society an invitation from our New York members to hold the spring meeting, 1911, in New York City.



THE 15-TON HEROULT ELECTRIC FURNACE AT SOUTH CHICAGO.

SESSION OF OCTOBER 15th.

The meeting was called to order at 9 A. M., in the Lecture Room of the Kent Chemical Laboratory, University of Chicago.

Papers by Edw. Gudeman, M. Ruthenburg (read by Jos. W. Richards), F. S. MacGregor, R. A. Millikan, J. C. Walton, Jr. (presented by L. Kahlenberg), L. Kahlenberg, D. Klein(presented by L. Kahlenberg), were presented and discussed, as printed in full in these Transactions. Papers by D. J. Block, H. E. Patten and W. R. Mott, C. F. Burgess and J. Aston, were read by title, and are printed in full in these Transactions.

Secretary Richards then moved, Mr. Carl Hering seconding, the following:

MOTION OF THANKS.

That the thanks of the American Electrochemical Society be conveyed to the:

Illinois Steel Company, of South Chicago; Indiana Steel Company, of Gary; Sears, Roebuck & Company; the Chicago Telephone Company; officials of the "Sanitary District" and the Lockport Power Station; the Commonwealth Edison Company, of Chicago; Western Electric Company; Automatic Electric Company; Hoskins Manufacturing Company; officials of the Union Stock Yards; Miss Jane Addams and the officials of the "Hull House"; the authorities of Chicago University; the management of Congress Hotel; the Local Committee of the Chicago Section, its chairman and secretary, and the chairmen of the sub-committees, and particularly of the "Ladies Committee"—for their courteous invitations to visit their establishments, and their very efficient services in furthering the success of the Eighteenth General Meeting of the Society.

The motion was carried by acclamation.

After adjournment, lunch was taken in the University Commons.

In the afternoon, many of the ladies visited the Field Columbian Museum, in Jackson Park. The bulk of the party took a special train on the Santa Fé Railroad to the Lockport power station, on the drainage canal. This was one of the most entertaining visits of the meeting, At Lockport, 35 miles from Chicago, the canal empties into the Des Plaines River, with a 36-foot fall. At this point there has been erected a modern power plant of 36,000 horse-power. This is the only large water

power near Chicago, and it is now available for lighting, power and electrochemical industries.

Following is the list of those in attendance at this very successful meeting:

Members and Guests Registered at the Eighteenth General Meeting.

Members.

Thos. B. Allen
Wm. H. Arison
C. B. Askew
Chas. E. Baker
F. M. de Beers
P. McN. Bennie
W. Bentley
E. J. Berg
David J. Block
Wm. Brady
Morgan Brooks
J. W. Brown
C. F. Burgess
W. W. Burson
L. C. O'Byrne
Jesse Coates
H. B. Coho
Fred L. Collins
R. T. Conger
H. R. Connell
W. A. Converse
J. S. Crider
Chas. W. Danforth
H. E. Diller
Ervin Dryer
J. A. Ede
S. H. Fleming
Geo. E. Folk
Karl G. Frank
Francis C. Frary
Arthur E. Gibbs
Jos. H. Goodwin
Albert E. Greene
Edward Gudeman
M. W. Hanks
Carl Hambuechen
M. W. Hanks
D. M. Hepburn
Carl Hering
P. Heroult
Wm. Hoskins
L. E. Howard
A. von Isakovics
G. J. Jenista
Arden R. Johnson
G. H. Jones
Grinnell Jones
L. Kahlenberg
Chas. C. Kawin.
Philo Kemery
Geo. O. Knapp
Otto Kney
M. M. Kohn
O. L. Kowalke
F. A. Lidbury
C. B. Lihme
M. G. Lloyd
F. H. Loveridge
Ernest Lunn
Jas. Lyman
F. S. MacGregor
Arba B. Marvin
H. T. Matthew
Harry McCormack
H. N. McCoy
J. M. Morehead
F. J. Newman
Chas. G. Osborne
Geo. S. Page
J. H. Parker
W. B. Pritz
A. Radtke
Amos G. Reeve
E. T. Rice
Jos. W. Richards
W. D. Richardson
E. F. Roeber
Pedro G. Salom
L. E. Saunders
Herman Schlundt
W. B. Schulte
R. C. Schwarz
John A. Seede
R. D. Small
E. S. Smith
Edwin H. Smythe
Fred T. Snyder
J. L. K. Snyder
E. A. Sperry
E. C. Sprague
S. G. Stafford
F. McM. Stanton
Walter M. Stein
L. L. Summers
Chas. E. Taylor
Edward R. Taylor
B. F. Thomas
C. B. Thwing
F. K. Vial
L. D. Vorce
W. H. Walker
O. P. Watts
H. K. Weld
F. B. Wheeler
C. S. Wickes
J. Rattray Wilson
Wm. L. Wilson
E. R. Wolcott
Edward Wray
W. V. Young
John A. Yunck
Edward Zaremba
J. G. Zimmermann

Guests.

Mrs. A. Bement
Mrs. Wm. Brady
Miss M. E. Gibbs
Miss Alice Henderson
Mrs. Wm. Hoskins
Mrs. A. von Isakovics
Mrs. J. H. Jackson
Mrs. Jas. Lyman
Mrs. Arba B. Marvin
Mrs. H. T. Matthew
Miss Eleanor Mayher
Mrs. H. N. McCoy
Mrs. W. D. Richardson
Mrs. F. T. Snyder
Mrs. E. R. Taylor
Miss E. B. Taylor

Thos. G. Allen
R. L. Ardrey
E. E. Arison
A. von Babo
Ernest Barnard
Wm. C. Bauer
A. Bement
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T. J. Bryan
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E. S. Clarage
E. L. Clark
F. D. Cockins
W. W. Coghill
G. W. Conway
R. A. Crider
G. M. Davidson
J. C. Dickerman
W. W. Dingee
H. Ehrlich
H. H. Engle
W. F. Faragher
E. Fenger
W. S. Ford
F. F. Fowle
E. Gottliels
B. E. Grant
D. H. Grant
W. H. Graves
J. B. Green
W. R. Greenlee
M. E. Hanna
G. W. Heise
H. A. Heise
W. T. Holmes
R. Hornbeck
W. C. Hovey
E. E. Hulbert
W. E. Kelly
A. Keiler
W. N. Kelsey
E. T. King
W. W. Kinsley, Jr.
Wm. Koula
G. Lawson
W. Leeds
O. Linder
J. A. Lounsburg
A. Lowenstein
W. P. Marseilles
G. M. Mayer
J. E. McCullough
W. T. Alan Merjies
P. C. Messinger
R. A. Millikan
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O. A. Olson
H. Pagenstecher
A. C. Parsons
C. R. Pierce
H. F. Plaff
F. B. Plummer
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H. C. Quigley
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O. E. Ruhoff
F. C. Ryan
M. Scharitz
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H. Schlesinger
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C. J. Schwarz
W. R. Smith
M. A. Spencer
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J. Stieglitz
J. A. Sutherland
C. O. Tibbals, Jr.
J. F. Towers
H. L. Trumbull
D. C. Ulray
Chas. Veat
C. H. Viol
Max von Vopelins
Paul C. Van Zandt
H. J. Wagner
E. W. H. Waldo
J. H. Warder
J. R. Warner
F. V. Wedlock
H. W. Young

Members Elected and Qualified.

May, 1910—November, 1910.

May 26, 1910.

S. G. Stafford, Coraopolis, Pa.
J. Ross Corbin, Sugar Loaf, Boulder Co., Colo.
B. G. Worth, Jr., Plainfield, N. J.
E. F. Hicks, Philadelphia. Pa.
C. S. Wickes, Philadelphia, Pa.
J. C. Andrews, Ithaca, N. Y.
Chas. V. Slocum, Pittsburgh, Pa.
Sidney Cornell, Duquesne, Pa.
E. L. Messler, Pittsburgh, Pa.
J. J. Eckfeldt, Latrobe, Pa.
B. D. Saklatwalla, Pittsburgh, Pa.
C. B. Gibson, Pittsburgh, Pa.
John S. Unger, Duquesne, Pa.
J. E. McKirdy, Pittsburgh, Pa.
O. S. Pulman, Lakewood, Ohio.
J. T. Brown, Jr., Pittsburgh, Pa.
A. D. Edwards, Pittsburgh, Pa.
Wm. J. Rich, Washington, D. C.
S. L. Goodale, Pittsburgh, Pa.
Jas. M. Graves, Pittsburgh, Pa.
W. B. Brookfield, Syracuse, N. Y.
R. L. Seabury, Lakewood, Ohio.
H. W. Fisher, Pittsburgh, Pa.
B. F. Hessom, Pittsburgh, Pa.
H. R. Connell, Brackenridge, Pa.
W. A. Donkin, Pittsburgh, Pa.
J. McKinley, Pittsburgh, Pa.
Kyosuke Iwai, Tokyo, Japan.
Emil Hensen, McKeesport, Pa.
B. Rutherford, Pittsburgh, Pa.
G. M. Goodspeed, McKeesport, Pa.
F. Uhlenhaut, Jr., Pittsburgh, Pa.
F. F. Farnham, McKeesport, Pa.
R. D. Small, Chicago, Ill.
A. Russell Calder, Steelton, Pa.

June 25, 1910.

G. P. McNiff, Munhall, Pa.
W. H. Hendricks, Palmerton, Pa.
L. M. Hartzell, Munhall, Pa.
R. A. McDonald, Pittsburgh, Pa.
Jas. H. Bradley, Pittsburgh, Pa.
E. T. Rice, Schenectady, N. Y.
Tadashi Hoshina, Tokyo, Japan.

July 29, 1910.

Reid T. Stewart, Pittsburgh, Pa.
Eduardo Guinle, Rio de Janeiro, Brazil.
Assar Groenwall, Ludvika, Sweden.
Otto Stalhane, Ludvika, Sweden.
Axel Lindblad, Ludvika, Sweden.
Otto Tingberg, Stockholm, Sweden.
A. Classen, Aachen, Germany.

August 26, 1910.

A. Burger, New Brighton, S. I. N. Y.
Chas. G. Osborne, South Chicago, Ill.
A. Liebmann, Newark, N. J.
E. J. Wolf, Brooklyn, N. Y.
B. C. Canet, New York City.
Chas. Mindeleff, Perth Amboy, N. J.
H. W. Gepp, Broken Hill, N. S. W., Australia.
F. E. Woodbury, Milwaukee, Wis.

September 24, 1910.

W. D. Richardson, Chicago, Ill.
Geo. J. Jenista, Chicago, Ill.
J. A. Leffler, Stockholm, Sweden.
Fredrik Jacobsen, Stavanger, Norway.
W. N. Walmsley, S. Paulo, Brazil.

October 29, 1910.

Einar Bjornson, Christiania, Norway.
C. W. Söderberg, Ski, Christiania, Norway.
W. B. Coleman, Philadelephia, Pa.
L. Mohr, Chicago, Ill.
Geo. H. Jones, Forest, Ill.

Joseph A. Ede, La Salle, Ill.
Kurt R. Sternberg, Springfield, Mass.
Wm. E. Oakden, Southbridge, Mass.
W. B. Schulte, Madison, Wis.
M. E. Hanna, Chicago, Ill.

November 26, 1910.

L. C. O'Byrne, Chicago, Ill.
Chas. C Kawin, Chicago, Ill.
J. H. Parker, Reading, Pa.
W. Bentley, Chicago, Ill.
G. Jones, Urbana, Ill.
S. H. Fleming, Cleveland, Ohio.
Thos. J. Bryan, Chicago, Ill.
Wm. B. Greenlee, Chicago, Ill.
F. W. Willard, Newark, N. J.
Wm. P. Marseilles, Niagara Falls, N. Y.
L. C. Turnock, Madison, Wis.
J. Tracy Lay, Philadelphia, Pa.

AMERICAN ELECTROCHEMICAL SOCIETY

DIRECTORY OF MEMBERS

December 1, 1910.

(Members of date April 3, 1902, are charter members.)

ABADIE, Eugene H. (Sept. 26, '08) Consult. Eng., 1720 Third Nat. Bank Bldg., St. Louis, Mo.; res., 5148 Westminster Place.
ABBE, Paul O. (Nov. 27, '09) Secretary, Abbe Engineering Co., 220 Broadway, New York City, res., 4434 11th Ave., Brooklyn, N. Y.
ABBOTT, William G. Jr., (Mar. 27, '09) care of Hillsboro Mills, Wilton, N. H.
ACHESON, E. G. (Apr. 3, '02) Inter. Acheson Graphite Co., Niagara Falls, N. Y.
ACHESON, Edward G., Jr. (July 31, '08) Pres. Acheson Oildag Co., Niagara Falls, N. Y.
ACKER, Chas. E. (Apr. 3, '02) care of Secretary.
ACKER, O. E. (Apr. 4, '03); Address unknown.
ADAMS, Prof. C. A. (Apr. 3, '02) Asst. Prof. of Elec. Eng., Harvard University, Cambridge, Mass.
ADAMS, Dr. Isaac (Apr. 3, '02) 1776 Massachusetts Ave., Cambridge, Mass.
ADAMSON, G. P. (Dec. 4, '02) Gen. Mgr. Baker & Adamson Chem. Co.; res., 233 Reeder St., Easton, Pa.
ADDICKS, Lawrence (Apr. 3, '02) Supt. U. S. Metals Refining Co., Chrome, N. J., res., 1037 East Jersey St., Elizabeth, N. J.
ADSIT, Charles G. (Sept 26, '08). Address unknown.
AHLBRANDT, G. F. (Jan. 29, '09) Open Hearth Supt., Amer. Rolling Mills Co., Middletown, Ohio.
AIKEN, Robert H. (Oct. 10, '03) Consulting Metallurgist, Winthrop Harbor, Ill.
AKERBERG, Tesdor, Dr. Phil. (Oct. 29, '08) Assistant Superintendent, Hoganas Billesholms A. B. Hoganas, Sweden.
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Bierbaum, C. H.
Childs, D. H.
Corse, Wm. M.
Doty, E. L.
Greene, F. V.
Mantius, Otto
Ramage, A. S.
Spalding, W. L.
Wilke, Wm.
Zaremba, Edward
Cazenovia—
Halcomb, Chas. H.
Clinton—
Saunders, A. P.
Corning—
Duschak, L. H.
Flushing—
Nash, A. D.
Glen Falls—
Hilliard, John D.
Hinckley—
McKee, G. M.
Ithaca—
Andrews, Joseph C.
Bancroft, W. D.
Lancaster—
Sayers, R. R.
Long Island City—
Lienau, J. H.
Lockport—
Harrison, H. C.
Kenan, W. R., Jr.
Mechanicsville—
Buckie, R. H.
Monticello—
Isakovics, A. von
Mt. Vernon—
Morgan, F. D.
New Brighton—
Burger, Alfred
Knorr, A. E.
Newburgh—
Walker, C. R.
New York City—
Abbe, Paul O.
Allyn, R. S.
Babcock, C. D.
Baker, H. A.
Baker, R. W.
Barr, B. M.
Barstow, W. S.
Baskerville, C.
Bijur, J.
Binney, Harold
Block, W. S.
Bogue, C. J.
Bowman, W.
Bradley, C. S.
Bradley, W. E. F.
Breneman, A. A.
Brown, H. P.
Brown, J. S.
Buck, H. W.
Buck, L. H.
Caldwell, E.

Cameron, W. S.
Canet, B. Chas.
Carse, D. B.
Cary, E. E.
Case, W. E.
Chandler, C. F.
Clark, W. G.
Clark, W. J.
Cleaves, M. A.
Coho, H. B.
Colcord, F. F.
Conlin, F.
Crocker, F. B.
Crumbie, W. D.
Dickinson, W. N.
Doerflinger, W. F.
Doremus, C. A.
Douglas, James
Dreyfus, W.
Du Bois, H.
Duncan, L.
Durant, E.
Dwight, Arthur S.
Edmands, I. R.
Eimer, A.
Elliott, A. H.
Englehard, C.
Eurich, E. F.
Falding, F. J.
Fitz Gerald, C. M.
Fitz Gibbon, R.
Foregger, R. von
Frank, K. G.
Frasch, H. A.
Frederick, G. E., Jr.
Fries, H. H.
Gaines, R. H.
Goepel, C. P.
Goodrich, C. C.
Granbery, J. H.
Grosvenor, W. M.
Hammer, W. J.
Harris, J. W.
Hart, C. D.
Hasslacher, J.
Hatzel, J. C.
Hay, J. A.
Hayes, Geo. W.
Heath, H. E.
Hemingway, F.
Hendry, W. F.
Heroult, P. L. T.
Herzog, F. B.
Hill, N. S., Jr.
Hirschland, F. H.
Hogel, H. A.
Hornsey, John W.
Howell, W. S.
Humbert, Ernest P.
Jenks, W. J.
Kahn, J.
Kennedy, J. J.
Kenyon, O. A.
Kenyon, W. H.
Kern, E. F.
Kirchoff, C.
Klipstein, E. C.
Kohn, M. M.
Kunz, G. F.
Lamb, A. B.
Langton, J.
Leavitt, Wm. F. B.
Lienau, J. H.
Loeb, M.
Love, E. G.
Lovejoy, D. R.
Lucke, H. J.
MacDonald, J. A.
Mailloux, C. O.
Martin, T. C.
Mastick, S. C.
Mayer, F. J.
Maynard, G. W.
Mays, E. A.
McAllister, A. S.
McBerty, F. R.
McKenna, C. F.
McMurtrie, W.
McNeill, R.
Mershon, R. D.
Merton, R.
Metz, H. A.
Monell, A.
Monrath, G.
Moody, H. R.
Morgan, J. L. R.
Morrow, J. T.
Morse, W. S.
Muir, J. M.
Muschenheim, F. A.
Nichols, W. H.
Nichols, W. S.
Nodell, W. L.
Parker, H. C.
Pattison, F. A.
Pearson, F. S.
Pennie, J. C.
Price, E. F.
Prindle, E. J.
Prosser, H. A.
Randolph, E.
Rawlins, J. A.
Reber, S.
Riker, J. J.
Robb, C. D.
Roeber, E. F.
Roller, F. W.
Rossi, A. J.
Rowland, L.
Ruhl, Louis
Schloss, J. A.
Schuetz, F. F.
Seward, G. O.
Sharp, C. H.
Skowronski, S.
Speiden, C. C.
Spice, R.
Stanton, F. McM.
Stevens, O. E.
Stoll, C. G.
Stone, I. F.
Stoughton, B.
Stovel, R. W.
Strong, A. H.
Stuetz, E.
Takamine, J.
Taylor, J. R.
Teeple, J. E.
Thatcher, C. J.
Thompson, J.
Thompson, R. N.
Tidd, G. N.
Toch, M.
Tucker, S. A.
Victorin, A.
Waddell, M.
Waldo, L.
Walker, A. L.
Waterman, F. N.
Weaver, W. D.
Wells, G. A.
White, J. G.
Widmann, E. A.

Wiechmann, F. G.
Wigglesworth, H.
Williams, A.
Williams, J. T.
Wills, J. L.
Winship, W. E.
Wittnebel, E. S.
Wolff, R. H.
Wood, E. F.
Worth, B. G., Jr.

Niagara Falls—
Acheson, E. G.
Acheson, E. G., Jr.
Allen, T. B.
Arison, W. H.
Banbury, F. H.
Barton, P. P.
Becket, F. M.
Bennie, P. McN.
Carveth, H. R.
Cole, E. R.
Converse, V. G.
Cox, G. E.
Dunlap, O. E.
FitzGerald, F. A. J.
Fowler, R. E.
Furness, G. C.
Giles, I. K.
Graham, J.
Greene, F. V.
Hall, C. M.
Hall, S. F.
Harper, J. L.
Haskell, F. W.
Hepburn, D. M.
Herzog, G. K.
Horry, W. S.
Hooker, A. H.
Imlay, L. E.
Kellogg, H. W.
Lidbury, F. A.
MacMahon, J.
Marseilles, W. P.
Marsh, C. W.
Marshall, J. G.
Mauran, M.
Meredith, W. F.
Moritz, C. H.
Moyer, G. C.
Ornstein, G.
Petitnot, N.
Phillips, R.
Randall, J. W. H.
Rayner, G. R.
Reilly, E. I.
Reeve, A. G.
Rodgers, A. G.
Ross, Wm.
Saunders, L. E.
Sergeant, E. M.
Simmers, A. L.
Smith, E. S.
Smith, W. A.
Speiden, E. C.
Sprague, E. C.
Spurge, E. C.
Stamps, F. A.
Stone, G. W.
Tone, F. J.
Vaughn, C. F.
Wallace, W.
Wilson, J. R.
Williamson, A. M.
Yoe, Harry A.

North Tonawanda—
King, R. O.

Ossining—
Snowdon, R. C.

Penn Yan—
Taylor, C. E.
Taylor, E. R.

Piermont—
Main, W.

Poughkeepsie—
Moulton, C. W.

Prince Bay, S. I.
Hammond, J. F.
Johnston, F. A.
Johnston, W. A.

Richmond Hill, L. I.
Haslwanter, C.
Maeulen, F.

Rochester—
Hutchings, J. T.
Parker, J. C.
Schwarz, R. C.
Willard, F. H.

Schenectady—
Arsem, W. C.
Bartlett, F. S.
Brunt Van, C.
Capp, J. A.
Creighton, E. E.
Diller, H. E.
Franklin, M. W.
Frodshain, H.
Hansen, C. A.
Langmuir, I.
Lindsay, C. F.
Murphy, E. J.
Reist, H. G.
Rice, E. T.
Rushmore, D. B.
Seede, J. A.
Steinmetz, C. P.
Whitney, W. R.
Willey, L. M.

Syracuse—
Brookfield, W. B.
Matthews, J. A.
Pennock, J. D.
Scott, W. H.
Sykes, H. W.

Troy—
Betts, A. G.
Lincoln, A. T.
Robb, W. L.

Union—
Giles, D. C.

Utica—
Johnson, M. H.
Schiller, F. W.

West New Brighton, S. I.
Ingalls, W. R.

White Plains—
Govers, F. X.

Yonkers—
Baekeland, L.
Harrington, E. I.
Statham, Noel

NORTH CAROLINA.

Chapel Hill—
Patterson, A. H.

Charlotte—
Gilchrist, P. S.

West Raleigh—
Browne, W. H.

NORTH DAKOTA.

Agricultural College—
Dolt, Maurice L.

OHIO.

Akron—
Geer, W. C.
Shaw, E. C.

Ashtabula—
Harrar, E. S.

Cincinnati—
Hutchinson, E. J.

Cleveland—
Brady, W. B.
Brown, J. W.
Chillas, R. B. Jr.
Clymer, W. R.
Collins, 2d, C. L .
Cowles, A. H.
Crider, J. S.
Fleming, S. H.
Graves, W. G.
Hobbs, P. L.
Hudson, A. J.
Humel, Edward J.
Hyde, E. P.
Koehler, W.
Lane, H. M.
Mann, W. W.
Mott, W. R.
Ordway, D. L.
Pritz, W. B.
Pulman, O. S.
Seabury, R. L.
Smith, A. W.
Snyder, J. L. K.
White, F. L.
Whitlock, E. H.
Woodward, J. M.

Columbus—
Allensworth, H. R.
Barnes, A. H.
Withrow, J. R.

Dayton—
Cridland, H. C.
Deeds, E. A.

Elyria—
Boynton, A. J.
Hitt, S. E.
Little, C. A.

Fostoria—
Downes, A. C.

Fremont—
Goodwin, J. H.

Lakewood—
Humel, E. J.
Mann, W. W.
Ordway, D. L.
Pulman, O. S.
White, F. L.

Lorain—
Boynton, A. J.

Middletown—
Ahlbrandt, G. F.

Salem—
Davis, D. L.

Toledo—
Clarke, W. A.

Youngstown—
Brinker, H. L.

OREGON.

Eugene—
Shinn, F. L.

PENNSYLVANIA.

Aliquippa—
Stafford, S. G.

Altoona—
Casselberry, H.
Walters, H. E.

Aspinwall—
Hessom, B. F., Jr.

Bethlehem—
Landis, W. S.
Rau, A. G.

Brackenridge—
Connell, H. R.
Scott, A. P.

Braddock—
Friedlaender, E.
Lewis, J. D.

Bridgeville—
Saklatwalla, B. D.

Canton—
Taylor, F. D.

Coatesville—
Coates, J.

Colwyn—
McConnell, J. Y.

Coraopolis—
Stafford, S. G.

Duquesne—
Cornell, S.
Reed, R. C.
Unger, J. S.

Easton—
Adamson, G. P.
Gordon, C. McC.
Hart, E.

East Pittsburgh—
Gibson, C. B.

Edgewood—
Donkin, Wm. A.

Gettysburg—
Parsons, L. A.

Ingram—
Armor, J. C.

Johnstown—
Kenney, E. F.
Parkhurst, C. W.

Latrobe—
Eckfeldt, J. J.

Lebanon—
Crowell, W. J., Jr.
Weimer, E. A .

McKeesport—
Clarke, E. B.
Farnham, F. F.
Goodspeed, G. M.
Hensen, Emil

Moore—
Werliin, G.

Munhall—
Hartzell, L. M.
James R.
McNiff, G. P.
Reese, P. P.
Stevens, R. H.
Wales, S. S.

Natrona—
White, R. H.

Oakmont—
Thomas, R. D.

Palmerton—
Hendricks, W. H.
Koch, S. B.
Smull, J. G.

Philadelphia—
Bacon, E. W.
Bower, F. B.
Breed, G.
Cary, C. R.
Chalas, Adolphe
Chance, H. M.
Clamer, G. H.
Decker, F. A.
Devereux, W.
Eglin, W. C. L.
Ely, T. N.
Fahrig, E.
Fernberger, H. M.
Flagg, S. G., Jr.
Fraley, J. C.
Furness, R.
Gardner, H. A.
Goldbaum, J. S.
Hering, C.
Hicks, Edwin F.
Hitchcock, F. R. M.
Hornor, H. A.
Howard, G. M.
Keith, N. S.
Kitsee, I.
Lafore, J. A.
Lavino, E. J.
Lay, J. Tracy
McConnell, J. Y.
McFarlin, J. R.
Meyer, J.
Morris, H. G.
Paul, H. N.
Perry, R. S.
Queneau, A. L.
Reed, C. J.
Russell, C. J.
Sadtler, S. P.
Sadtler, S. S.
Salom, P. G.
Schamberg, M.
Smith, E. F.
Smith, E. W.
Smith, W.
Snook, H. C.
Steinmetz, J. A.
Stevens, J. F.
Taggart, W. T.
Thwing, C. B.
Weeks, C. A.
Werliin, Godwin
Wickes, C. S.
Williams, H. J.

Pittsburgh—
Amberg, Richard
Babb, Jos. E.
Barrett, J. M.
Bradley, Jas. H.
Brown, John T., Jr.
Crabtree, F.
Davis, S. A.
Donkin, Wm. A.
Edwards, Albert D.
Fisher, Henry W.
Flannery, Jas. J.
Goodale, S. L.
Graves, Jas. M.
Hartley, R. H.
Hessom, B. F., Jr.
Isaacs, A. S.
James, J. H.
Kemery, P.
Kier, S. M.
Laughlin, H. H.
Lincoln, P. M.
Mason, E. J. K.
McDonald, R. A.
McKinley, Jos.
McKirdy, John E.
Merrill, J. L.
Messler, E. L.
Mueller, H. N.
Murphy, D. H.
Ober, J. E.
Orr, R. S.
Osborne, L. A.
Page, G. S.
Pinkerton, A.
Rodman, H.
Rutherford, B.
Saklatwalla, B. D.
Schluederberg, C. G.
Scott, C. F.
Sill, H. F.
Slocum, Chas. V.
Slocum, F. L.
Snelling, W. O.
Speller, F. N.
Stewart, R. T.
Sturgess, F. M.
Uhlenhaut, F., Jr.
Vogt, C. C.
Wiley, B.
Yardley, J. L.

Pottstown—
Coleman, W. B.
Cook, E. B.
Wiley, B.

Pottsville—
Chance, E. M.

Primos—
Boericke, G.
Stein, W. M.

Reading—
Parker, Jas. H.

Scranton—
Bryden, C. L.

Sewickley—
Wadsworth, F. L. O.

Sharon—
Lytle, C. W.
Warren, G. S.

Sinnamahoning—
Gray, C. W.

South Bethlehem—
Acker, C. E.
Buck, C. A.
Franklin, W. S.
MacNutt, B.
Richards, J. W.
Seyfert, S. S.

South Sharon—
Samuels, W. P.

State College—
Hillegass, H. H.
Pond, G. G.
Richardson, H. K.
Taylor, F. D.

Steelton—
Calder, A. R.
Carney, F. D.
Dougherty, J. W.

Swissvale—
Edge, D.
Sturgess, F. M.

Tarentum—
Connell, H. R.
Hitchcock, H. K.

Tyrone—
Bachert, A. E.

Vandergrift—
Bennett, B. F.

West Pittsburgh—
Buch, N. W.
Wilkinsburg—
Gibson, Chas. B.
Skinner, Chas. E.

RHODE ISLAND.

Greene—
Perry, C. M.
Newport—
Richards, E.
Providence—
Catlin, C. A.
Saunders, W. M.
Slade, W. C.

SOUTH CAROLINA.

Camden—
Mills, J. E.
Charleston—
Stanley, Wm.
Clemson College—
McAdam, D. J.
Sumter—
Deventer, Van, H. R.

TENNESSEE.

Chattanooga—
Thomas, B. F.
Clarksville—
Faust, T. B.
Nashville—
Dudley, W. L.

TEXAS.

Austin—
Harper, H. W.
Shoch, E. P.
Big Springs—
King, J. E.
Fort Worth—
Boon, J. D.
Galveston—
Wichman, H. J.
Victoria—
Lewis, J. B.

UTAH.

Provo City—
Smith, F. W.
Salt Lake City—
Emery, W. L.
Jennings, E. P.
Merrill, J. F.

VIRGINIA.

Fredericksburg—
Montague, Chas. D.
Holcomb's Rock—
Kugelgen, F. von
Lee, H. R.
Norfolk—
Webb, L. W.
Roanoke—
Engle, H. M.

WASHINGTON.

Irondale—
Merzbacher, A.
Seattle—
Crim, L. P.
Spokane—
Armstrong, L. K.
Woodwell, A. H.
Tacoma—
Brandt, O. T. D.
Everette, W. E.

WEST VIRGINIA.

Clarkesburg—
Chorpening, G. B.
Oesterle, W. F.
Glen Ferris—
Huffard, J. B.
Morgantown—
Hite, B. H.
Wheeling—
Hearne, D. G.

WISCONSIN.

Appleton—
Lathrop, L. H.
Eau Claire—
Peirce, A. E.
Madison—
Aston, J.
Beebe, M. C.
Bennett, E.
Burgess, C. F.
Breckenridge, J. M.
Gorman, H. B. L.
Hambuechen, C.
Hirsch, Alcan
Kahlenberg, L.
Kowalke, O. L.
Schulte, W. B.
Turnock, L. C.
Watts, O. P.
Milwaukee—
Kremers, J. G.
Lord, Chas. E.
Vogel, G. C.
Woodbury, F. E.
Zimmermann, J. G.

WYOMING.

Thermopolis—
Freeman, G. N.

CANADA.

British Columbia,
Ashcroft—
Bales, H H.
Heriot Bay—
Bagot, C. G.
Greenwood—
Keffer, F.
Nelson—
Fowler, S. S.
Trail—
Aldridge, W. H.
Vancouver—
Barwick, W. S.
Boesch, J. E.
Hayward, R. F.
Kendall, G. R.
Manitoba,
Winnipeg—
Morden, G. W.
Nova Scotia,
New Glascow—
Cantley, T.
Ontario,
Cobalt—
Evans, J. W.
Copper Cliff—
Browne, D. H.

Deloro—
Kirkegaard, P.
Fitzroy Harbor—
Simpson, L.
Gowganda—
Colvocoresses, Geo. M.
Kingston—
Goodwin, W. L.
Guttmann, L. K.
Niagara Falls—
Beckman, J. W.
Cooper, K. F.
Rowland, T.
Sault Ste. Marie—
Sjostedt, E. A.
Soskatoon—
MacLaurin, R. D.
St. Catharines—
Heitmann, E.
Turnbull, R.
Toronto—
Cohoe, W. P.
Dushman, S.
Kaemmerer, J. A.
Miller, W. L.
Redman, L. V.
Tate, Alfred O.
Watts, Geo. W.
Quebec,
Montreal—
Girdwood, G. P.
Hough, A.
McIntosh, D.
Stansfield, A.
Walker, J. W.
Ottawa—
Haanel, E.
Haff, M.
Morgan, L. C.
Shawenigan Falls—
Witherspoon, R. A.

COSTA RICA.

Puntaremus—
Fraser, Lee

CUBA.

Havana—
Seidel, C. M.
Isle of Pines—
Roberts, I. L.

MEXICO.

El Oro—
Beignet, R.
Girdwood, K. J.
Mexico City—
Brindley, Geo. F.
Ferguson, W. A.
Villarello, J. D.
Vrooman, H. H.
Wilkins, E. M.
Teguisguiapan—
Honey, W.
Tezuitlan—
Watson, Ralph A.
Torreon—
Mills, H. P.

NEWFOUNDLAND.

St. John's—
Harvey, E. F.

PANAMA.

Culebra—
Schildhauer, E.

SOUTH AMERICA.

ARGENTINE REPUBLIC.

Buenos Aires—
Newbery, Jorge
Stone, J. P.

BRAZIL.

Rio de Janeiro—
De Medeiros, T. S. V.
Guinle, Eduardo
S. Paulo—
De Souza, E.
Walmsley, W. N.
Villa Nova de Lima—
Gill, T. P.
Jones, H.
Wilder, F. L.

CHILI.

Antofagasta—
Atwood, C. E.
Rancagua—
Langford, F.
Santiago—
Blanquier, J. T.
Diaz-Ossa, B.

COLUMBIA.

Bogota—
Calvo, P. P.
Pasto—
Gamba, F. P.

PERU.

Cerro de Pasco—
Guess, Geo. A.
Lima—
D'Ornellas, T. V.
Holstein, O.

AUSTRALASIA.

NEW SOUTH WALES.

Broken Hill—
Gepp, H. W.
Port Kembla—
Johns, M. J.
Lawson, J. L.
Magnus, B.
White, E. A.
Moonta Mines—
Hancock, H. L.
Sydney—
Corin, W.
Waratah—
Schroeder, H.

NEW ZEALAND.

Dunedin—
Creagh, E. C.
Stark, E. E.
Epsom—
Gordon, H. A.
Wellington—
Fahy, J. T.

QUEENSLAND.

Brisbane—
Jackson, A. G.
Mt. Morgan—
Du Faur, J. B.
Richard, G. A.

TASMANIA.

Queenstown—
Sticht, R. C.

VICTORIA.

Ballarat—
Oddie, J.

AFRICA.

CAPE COLONY.

Somerset, West—Quinan, K. B.

ASIA.

CHINA.

Lin-sien—
Kwong, Y. K.

INDIA.

Bangalore—
Arunachela, T. K.
Calcutta—
Smythe, C. V.
Rejouli—
Dickson, A. A. C.
Kankanhalli—
Tate, J. V. E.
Simla—
May, Alex

JAPAN.

Kure—
Tada, S.
Kyoto—
Namba, M.
Nishikawa, K.
Yoshikawa, K.
Naganoken—
Takahashi, T.
Takata—
Kunitomo, S.
Tokyo—
Hoshina, T.
Iwai, K.
Katsura, B.
Kishi, K.
Masujima, B.
Oshima, Y.

PHILIPPINE ISLANDS.

Manila—
Dalburg, F. A.

EUROPE.

AUSTRIA-HUNGARY.

Prague—
Babrowsky, G.
Vienna—
Paweck, H.

BELGIUM.

Brussells—
Moltkehansen, I. J.
Solvay, A.

FINLAND.

Helsingfors—
Oholm, L. W.

FRANCE.

Albertville—
Aubry, H.
Paris—
Drake, F. E.
Gall, H.
Garfield, A. S.
Gin, G.
Keller, C. A.
Marie, C. A.
Ostheimer, J. W.
Riva-Berni, A.
Saint Cloud—
Sang, A.

GERMANY.

Aachen—
Classen, A.
Berlin—
Glenck, I.
Reichel, W.
Charlottenburg—
Engelhardt, V.
Clausthal—
Hoffmann, R.
Essen-Ruhr—
Goldschmidt, H.
Frankfort—
De Neufville, R.
Liebmann, L.
Hamburg—
Wohlwill, H.
Hanau—
Heraeus, H.
Hoechst—
Reisenegger, H.
Karlsruhe—
Haber, F.
Leipzig—
Le Blanc, M.
Schall, C.
Wagner, J.

Lubeck—
Draeger, A. B.

Niederschoeneweide—
Calberla, R.

Radebeul—
Ashcroft, E. A.

Werdigen—
Meyer, F.

GREAT BRITAIN.

Birmingham—
Smith, C. A.
Threlfall, R.

Cardiff—
Ewing, A. J.

Letchworth—
Foster, C. E.

Liverpool—
Smith, A. T.

London—
Campbell, D. F.
Cowper-Coles, S.
Merz, C. H.
Ruthenburg, M.
Shields, J
Taylor, W. T.
Wetzler, Joseph

Manchester—
Pring, J. N.

Sheffield—
Fawcett, P.
Hadfield, R. A.
Hutton, R. S.
Rowland, T.

St. Helens—
Le Mare, E. B.

West Ealing—
Irvine, H. A.

ITALY.

Aguila—
Dapples, A.

Rome—
Catani, R.
Chiaraviglio, D.
Morani, F.

Turin—
Giolitti, F.
Stassano, E.

NORWAY.

Bergen—
Irgens, J. F.
Petersson, A.

Christiania—
Bjornson, E.
Hiorth, F. V. L.
Johansen, G. H.

Jossingford—
Cornthwaite, S.

Ski—
Soederberg, C. W.

Stavanger—
Jacobsen, F.

RUSSIA.

St. Petersburg—
Emrich. H. H.
Lodyguine, A.

SPAIN.

Rio Tinto—
Shields, J.

SWEDEN.

Falun—
Ljungh, H.

Gothenburg—
Appelberg, A. O.

Gullspang—
Hedlund, M.

Hoganas—
Akerberg, O. T.
Forssell, J.

Ludvika—
Groenwall, Assar
Lindblad, Axel
Stalhane, Otto

Mansbo—
Carlson, B.

Stockholm—
Kjellin, F. A.
Leffler, J. A.
Tingberg, Otto

Trollhattan—
Cornelius, E.
Olausson, K. O. E.

Vesteras—
Edstrom, J. S.

Westervik—
Tillberg, E. W.

SWITZERLAND.

Basel—
Fichter, F.

Geneva—
Bonna, A. E.
Gandillon, A.
Guye, P. A.
Lacroix, H.

Vernier—
Von Bidder, F.

Zurich—
Liebmann, A. J.
Voge, A. L.

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THE EVOLUTION OF THE LEAD STORAGE BATTERY.

By Pedro G. Salom.

To the lay mind there is something mysterious about a storage battery. Even otherwise well-informed electrical engineers, while thoroughly conversant with the practical working of a battery, are sometimes puzzled in attempting to explain its *modus operandi.*

But there is nothing more mysterious about a primary battery or a secondary battery, otherwise known as an "accumulator" or "storage battery," furnishing a current of electricity than a piece of coal burning in a grate or under a boiler. In both cases, energy is set free by chemical combination, in one case manifesting itself as heat, and in the other as electricity. It is only a little over one hundred years ago that the common phenomenon of combustion or burning of bodies was far more mysterious than the telephone or wireless telegraphy is to-day. They discovered then that combustion in a general sense was the chemical combination of carbon and oxygen, and that the heat developed was due to the potential energy resident on the particles or atoms of carbon which is set free at the moment of their combination with oxygen.

When a piece of zinc is placed in sulphuric acid, a tumultuous ebullition takes place and hydrogen gas is liberated. But another phenomenon also takes place, and that is that the liquid becomes heated. This, therefore, is another form of chemical combination which produces heat by the union of zinc and sulphuric acid, forming sulphate of zinc and hydrogen. If, however, we were to introduce at the same time with the zinc a piece of copper and connect the ends of each with a wire, a new phenomenon takes place, and instead of heat, we have a current of electricity; and if we were to accurately measure the amount of mechanical work done by the heat and by the current of electricity, we would find it to be exactly the same in both cases, showing that heat and

electricity are quantitatively related and are merely different manifestations of a primordial force.

Now a storage battery produces an electric current in a manner exactly similar to that described above, only in the case of a lead storage battery we are combining lead with sulphuric acid instead of zinc, and are making sulphate of lead, which, being insoluble in sulphuric acid and water, remains in the plate instead of going into solution like sulphate of zinc.

The reverse current arising from plates of the same metal which previously had a current of electricity passed through them was discovered by a French chemist named Gautherot, in 1801. It was at first thought that the electricity, which at that time was considered a fluid, was absorbed by the plates and then given out again. But the chemists soon demolished this theory and showed that the action and reaction were due to the chemical decomposition when the current was passed through the plates, or what we now call "charging," and to chemical combination thereafter when the plates returned the current, which we now call "discharging." In 1859, Gaston Planté found that the best effects could be produced by placing two sheets of lead in sulphuric acid and alternately charging and discharging. The result of this action, by reversing the polarity of the current, was to ultimately convert one of the sheets of lead into spongy lead and the other into peroxide of lead, "the active materials" of a storage battery; but it required weeks and months to accomplish this result, and when completed, the plates at that time made from thin sheets of lead, being all converted into spongy lead and peroxide of lead, no longer had any structural strength, and simply crumbled away or fell to pieces. Planté studied the subject exhaustively and discovered the general principles underlying the storage battery as known today.

The dynamo not yet having been invented, and therefore no cheap source of current for charging, a Planté battery became a highly interesting and instructive piece of laboratory apparatus without any commercial value. With the advent of the dynamo in 1876, the value of a storage battery was at once apparent, and a number of chemists and physicists set to work to improve the Planté battery so that it could be used in conjunction with the dynamo to store surplus energy and return the same when

the dynamo ceased to run. Prior to that time storage batteries had to be charged from primary batteries, which, of course, was an expensive operation.

In 1881, Brush and Faure simultaneously and without each other's knowledge made a great advance in the art, by applying to the lead sheets *material* adapted to become active by simply passing the current through in one direction, and "forming" or converting into spongy lead and peroxide of lead on the negative and positive plates, respectively, instead of making the active material by the disintegration of the lead sheets themselves. This so-called active material consisted of oxides of lead, usually litharge and red-lead. This materially hastened the manufacture of the plates and reduced the time of formation from months to a week or ten days. The first commercial efforts of Faure were very clumsy and unsatisfactory, and his batteries were not as good as the Planté type. He had, however, enormously increased the ampere hour or electrical capacity of the plates pound for pound of battery. The principle was right, and as soon as a little mechanical skill was introduced into their manufacture, they rapidly superseded to a very large extent the Planté type. This was accomplished by using a lead "grid" or frame for holding the active material which was "pasted" in the holes or receptacles of the grid or frame, the latter being known as the "conducting support," because it served to support the oxides of lead and at the same time conducted the current which formed them into spongy lead and peroxide or "active material" on "charging," and allowed the current generated, by combining the spongy lead with sulphuric acid, to flow back on "discharging."

So far as we know, Brush never made any efforts to make a commercial battery of his new type, but confined himself to laboratory experiments. Since 1881 there have been no patentable improvements over the Brush-Faure type of battery except in details of mechanical construction, all the plates now in use being of the Planté or of the "pasted" (Brush-Faure) types.

Now the natural evolution of the subject was to carry the process one step further and to fill the plates with real active material (spongy lead and peroxide) previously made in bulk, such plates constituting a thoroughly "formed" and finished battery, practically ready for immediate use, without any subsequent

operations being required. This result has been accomplished in the battery which I have the honor to call your attention to to-day, made of what I call "initially" formed plates, with surprising results, combining as it does all the advantages and none of the disadvantages of both the old types.

It is not the purpose of this paper to discuss in detail the manufacture of Planté and pasted plates, but merely to call your attention to the principal methods employed, for the purpose of comparing the resulting products with those of "initially" formed plates. With the early type of Planté plates we have nothing to do, as they are no longer in use and never had an extensive commercial application. Before and after the introduction of the Brush-Faure type of battery, efforts were made to improve the Planté type, which have been more or less successful. The first efforts were made in the direction of hastening the formation. This was accomplished in two ways, first, by increasing the surface area of the plate by innumerable grooves or indentations, either by casting pure lead plates with such grooves, or by mechanical means cutting the surface of a rolled lead sheet into thousands of leaves or laminations, which are spun up by means of discs or cutters, so that the finished plate is about double in thickness the original sheet lead, with the superficial area increased ten-fold, that is to say, a plate originally ten inches square, with a superficial area of 100 square inches, would be increased to a superficial area of 1,000 square inches.

These leaves or laminations, being exceedingly thin, are readily attacked by chemical or electrochemical operations, ultimately converting the oxidized portions into peroxide, which in turn is reduced to spongy lead for negative plates.

In the chemical process of rapid formation, some acid which will readily dissolve lead, like HNO_3, is employed and the resulting soluble lead salt is acted upon by other chemicals to produce an insoluble lead salt in the supernatant liquor, like sulphate or carbonate of lead, which are readily converted into peroxide by the subsequent action of the current. But this method is objectionable on account of the difficulty of removing all the nitric acid after formation.

The electrochemical methods employed are based on the principle of oxidizing the lead at the positive electrode by oxidizing

agents in the electrolyte such as nitric or acetic acid mixed in various proportions with the usual sulphuric acid solution. Now on the manner in which this chemical or electrochemical process is conducted, the character of the chemicals used in the electrolyte, the temperature and the current density, depend the *character and quality* of the resulting peroxide and subsequently the sponge made from the same, as well as its mechanical adherence to the plate and its own cohesive properties. All these conditions are hard to control, whereas in "initially" formed plates we can apply both the peroxide and sponge separately produced in any physical condition calculated to give the best results in the finished plates. Pure peroxide of lead has little or no cohesive or adhesive qualities *per se,* and the active material in a newly formed Planté positive is in a somewhat similar physical condition to a badly overcharged pasted positive, except that the masses of Planté peroxide are, of course, much smaller than those in the pasted positives, but they (the masses) are also considerably denser when the plates have been properly formed, hence the better mechanical and electrical contact with the conducting support. The peroxide made by direct oxidation of the lead is, of course, much denser than that made by dissolving the lead and subsequent precipitation and oxidation, but the spaces between the laminations are so small that it is sufficiently dense to afford comparatively good conductivity. But in this condition the peroxide is readily washed off the plate by the circulation of the electrolyte, and large pieces which have become detached from the body of the plate or leaves scale off. Additional portions of peroxide are made by the succeeding charges, and the plates maintain their capacity so long as the solid lead holds out and, indeed, often increase in capacity, up to about the 50th cycle.

Now in discharging the plate the peroxide is converted into sulphate, and this sulphation can be carried to a greater degree in a Planté plate than a pasted plate, because the masses of active material are so thin and in such close proximity to the grid as not to seriously affect the conductivity of the active material and thus increase the internal resistance, until a very substantial amount of the peroxide is converted into sulphate, and for the same reasons can be restored or converted again into peroxide on recharging. A serious overcharge of a Planté plate is theo-

retically as bad as in a pasted plate, but practically it does not wash away as rapidly, owing to the narrow retaining grooves and spaces.

As a Planté battery weighs about twice as much as a pasted battery for the same ampere hour capacity, there would be no reason for its use were it not for the fact that it has a much longer life. How much longer I am not prepared to say, because the conditions under which both types are used vary to such an extent that a comparison is difficult. In general, however, I think it would be safe to say two or three-fold; but where large ampere rates of discharge are required with a minimum weight of battery, such as in electric vehicle service, the Planté is impossible; and where long life is required with comparatively low rates of discharge, and where the element of weight is not vital, such as in railroad car lighting, the Planté type seems to have won the field.

We may say, then, that the only advantage the Planté type possesses over the pasted type is in length of life, and this becomes negligible if the ratio of weight to ampere hour capacity is sufficiently low in the pasted type to permit of sufficient renewals to accomplish the work for the same price. In other words, a pasted battery of half the weight and half the life of a Planté battery would be just as cheap to the consumer as a Planté battery, assuming that the cost per pound of each battery was the same.

The disadvantages of a Planté battery are the small ampere hour capacity per pound and the expansion which takes place in the positive plates owing to the growth or increase of peroxide.

Dozens of processes have been proposed for the rapid formation of Planté plates, some of them of such a highly complicated and expensive character that even if the extravagant claims for them were realized, they would be entirely without the pale of a commercial proposition. The best information we have on the subject is that the quick, simple methods of chemical and electrochemical formation are the best.

Let us now consider for a moment the manufacture of pasted plates. Here the grid is of vital importance and it would take a day to describe the many ingenious forms and devices that have been invented for the purpose of holding the active material securely and firmly in place and to secure the maximum area of

conducting support and maximum weight of active material with the minimum amount or weight of conductor. These fantastic grids, however, like the complicated methods proposed for forming Planté plates, have had no extensive commercial application and only a few types are now in general use, the most important being the "Swan"; the corrugated or recessed grids, not perforated, like the Tudor; staggered grids, such as the positives made by the Electric Storage Battery Co. and the National Co., and lattice-work grids, such as the Correns and the Philadelphia Battery Co. make.

In filling grids of the Brush-Faure type, the material to become active is first made into a paste and applied to the "grids" or supports, and afterwards "formed" or converted into active material by the action of an electric current.

For negative plates, under this process, litharge (oxide of lead) is mixed with about 25 percent of diluted sulphuric acid into a paste, which is applied to the lead grid, then dried, and, in some cases, baked. The plates are then put into an acid bath and a low rate of current passed through them for about a week. For positive plates the paste is made of red-lead or red-lead and litharge, applied to the grids in a similar manner and then dried and formed.

As in the case of grids, numerous other methods and mixtures have been proposed, but all the large manufacturers have substantially adopted the process described above. The advantages of the Brush-Faure type of plates over the Plantè are the large ampere hour capacity per pound and the smaller space required for a given output.

The disadvantages are the comparatively large size pellets or cross-sectional area of the active matter, shrinkage of the active material in the negative plates, expansion of the active material in the positive plates and the consequent shortness of life.

Now, in a pasted negative, suppose the amount of litharge, acid and water weighs 1 lb., when the 25 percent water and sulphuric acid is removed, only 0.75 lb. of litharge remains, and 8 percent oxygen removed from this, or 0.06 lb., leaves 0.69 lb. of pure spongy lead which would remain in the plate after formation if the plate could be taken out, thoroughly washed and dried in vacuum. This 31 percent loss accounts for the enormous

shrinkage of the active material in the negative plate and its comparative inefficiency and shortness of life.

Many schemes have been resorted to by battery manufacturers to overcome this difficulty. All sorts of materials have been added to the paste, some active, others inert, like ground pumice stone, graphite (even flour has been used), etc., and it is really singular that none of them have recognized the fact that what they need in the plate is more spongy lead.

In "initially" formed negative plates the grids are filled with from 95 to 97 percent of pure spongy lead, with comparatively little moisture and oxygen, so that we have actually 25 percent more spongy lead in the same size and shape of grid than a pasted plate contains.

"Initially" formed positive plates are filled with pure peroxide of lead, uniformly mixed with a binder and then compressed under enormous pressure into a coherent mass having a perfect electrical and mechanical contact with the grid or support.

In forming pasted plates made by mixing red-lead and litharge with sulphuric acid, if the formation is complete, so that the active material is all converted into pure peroxide, the active material is soft like mud. If it is not completely formed, of course the capacity of the plate is diminished to the extent of the percentage of the unformed material.

The peroxide in "initially" formed plates is fully formed and held in place and in mass by a sufficient amount of binder in the form of sulphate to make the active material solid and firm. You can readily understand that there is a vast difference between the peroxide formed from sulphated litharge and red-lead, and peroxide mixed with a binder and then sulphated as a mass, as sulphate of lead is the natural "binder" or "cement" for holding together the non-cohesive and non-adhesive particles of peroxide. In the former case the mass consists of peroxide containing no sulphate or binder, and sulphate of lead entirely distinct from each other, so far as a mixture of the same is concerned; and in the latter the total amount of peroxide is entirely surrounded by a protective coating or cement of sulphate and intimately mixed therewith, making a homogeneous solid mass. In one case the active material is soft and muddy, and in the other a firm, solid mass, in which the sulphate used as a binder is never removed

under proper working conditions, except on the surface, until the entire amount of active material is removed from the grid.

The great advantages, therefore, of "initially" formed plates over pasted plates are their increased capacity, amounting in many cases to 25 percent or more, as will be seen by reference to the curves herewith submitted, their increased life amounting to over 100 percent for negative plates and perhaps several hundred percent, as we have not yet had sufficient time to determine this question, but the indications, after over 7,000 miles of service in electric vehicle traction (the most severe service that battery plates ever receive), without any sensible depreciation, all point to an expectancy in life never before realized and 5 percent higher potential, or about 1/10 of a volt, due to the better mechanical and electrical contact with the conducting support.

The advantages over Planté plates are their increased capacity of at least 50 percent pound for pound of battery with a life at least comparable with the best Planté plates; freedom from the expansion due in Planté plates to the progressive oxidation of the positive conducting support on each successive charge; freedom from the necessity of frequent washings due to the accumulation of the active material in the bottom of the cell. Our plates being only about one-third the thickness of Planté plates, double the number of a smaller size can be placed in the same size cell, thus leaving ample space in the bottom for the accumulation of the positive active material during the life of the battery without any washing being required.

When it comes to the question of manufacture, the methods employed by us are so simple and efficient that comparisons with either of the old types are impossible. The fact of being able to construct a finished working battery in from 15 to 20 minutes, compared to the older processes of forming Planté plates or pasting and then forming Brush-Faure plates, operations requiring days and even weeks of time, puts "initially" formed plates in a class entirely alone. And when this can all be effected with a material reduction in the cost of manufacture, increased capacity and higher voltage, it is evident what a tremendous advance has been made in the storage battery art.

In conclusion I would say that we appear to have all the factors

of both Planté and pasted plates under control. In our negative plate we have the life of the Planté and the capacity of the pasted type. In the positive plate we have a range from the high capacity of the pasted type to the longer life of the Planté by varying the amount and size of the masses of peroxide according to the requirements of the service, and in both cases there is no forming or other subsequent operations after the plates leave the press. The battery is finished as soon as the plates are mounted, and shows a difference of potential of from 1.66 to 1.8 volts before ever having been charged, and comes up to its full ampere hour capacity after the third or fourth charge and discharge.

I particularly desire to express my indebtedness to Mr. D. M. Hepburn for his careful, intelligent and exhaustive investigation of this subject.

DISCUSSION.

Mr. E. A. Sperry: This whole storage battery proposition has always interested me, and when we say "lead storage battery," there comes into our mind usually something very heavy and ponderous as compared with the amount of power it will store.

Some years ago I had occasion to make some investigation with reference to the amount of power that could be stored in other ways, and that comparison, no doubt, would be interesting to you. At that time lead batteries were being made that would deliver one electrical horse-power hour for each 80 pounds. That is, all told and everything complete. At that time they were running some compressed air cars in New York City. The compressed air was at about 2,400 pounds per square inch (160 atmospheres), contained in steel bottles as light as they dared be made for that pressure, and it was found that although that air was re-heated, which greatly added to its power factor, yet the air (which weighed about 12 pounds per cubic foot when compressed to that pressure), together with the bottle, stood at about 220 pounds per horse-power hour (not counting in the weight of the re-heater), as compared with 80 pounds for the battery made from lead. Many, nevertheless, associate the lead

cell in their minds as being an extremely heavy and cumbersome affair as compared with the amount of power it will store.

About this time tests were made with the Edison battery, showing about 100 to 110 pounds to the electric horse-power hour, according to the amount of overcharge received by the battery. I understand these figures have been cut down materially, and on heavy overcharge some tests have gone as high as 15 watt hours per pound, which would be about 50 pounds to the horse-power hour. In Germany very light batteries are being used that run 12 watt hours to the pound, which would be about 62 pounds to the horse-power hour. Some investigations I made in Berlin last summer reveal the fact that an effort has been made for sometime past in the same line as that of Mr. Salom, namely, a cheap battery with limited life. I have myself done some work in this line in the past and thoroughly believe that this is a practical method of getting the best results. My work in this line has extended to developing uses for the by-product constituting the returned batteries which would be exchanged for new ones. If proper use is made of this material, it may be valued at very much more than scrap material, thus permitting cheaper renewals being made at a profit to the manufacturer.

Mr. Salom: Here is a negative plate that has made 4,000 miles; it is just as good as or better than the new negative plate which I have just shown you, and which, of course, has not been used. This is accounted for by the fact that it is now more or less sulphated, owing to being discharged. You can see from the appearance of it that there is actually no deterioration in it whatever. The same battery from which this plate was taken has now made over 7,000 miles, and to all appearances the plates are just the same as the sample shown. They do not show any shrinkage whatever, and really look as good as new plates. Now, here is a positive plate which has made 50 cycles, and you can still see, if you hold it in the right light, the fabric or cloth which was laid on top of it at the time of pressing, showing that a very small amount of active material has been washed away from the positive plate; this, of course, is unavoidable in a positive plate. Here is a sample of a pasted negative that I brought not for any idea of comparison, but merely to show the 31 percent of material which has been taken out of it after pasting. I do

not know what treatment this plate has received. It was taken from a battery received at the factory, and we know nothing of its history except that its appearance indicates that it has been badly overworked and the active material completely destroyed as an active agent.

Mr. ——: Do I understand that the method has been applied to a negative plate which has lost its capacity, by dipping in a sugar solution?

Mr. Salom: I think such an application is merely one of those fantastic things which have no commercial value at all. The better electrical and mechanical contact of the active material to the grid increases the voltage about 1/10 of a volt, and the capacity is in many cases as much as 25 percent greater than the ordinary pasted plate, even at high rates of discharge. Here are discharge tables of a type 9 L. V. This is the same as

Table I.

Record of discharge of a Niagara Lead and Battery Co's vehicle battery, type 9 L. V., corresponding in size and weight with other makes of vehicle batteries rated at 24 amperes for 4 hours, or 96 ampere-hours. Second discharge ran 5 hours, 8 minutes at 23.6 amperes; capacity shown 120 ampere-hours.

	Voltage.
Start	2.20
1 Hour	2.11
2 "	2.04
3 "	1.99
4 "	1.90
5 "	1.72
End	1.70

Table II.

Record of third discharge of same battery; 5 hours at 24 ampere rate, output 120 ampere-hours.

	Voltage.
Start	2.20
1 Hour	2.09
2 "	2.00
3 "	1.90
4 "	1.84
5 "	1.70

the type 9 P. V. of the Electric Storage Battery Company, which battery is rated at 24 amperes for four hours, or 96 ampere hours. You will see that we get at 23 6/10 amperes a little over 5 hours, and at 24 amperes, just 5 hours' discharge.

Mr. W. Bentley: I would like to ask Mr. Salom about that statement of the shrinkage in the negative active material being

due to the loss in weight of the paste before it is formed. If that is the cause of the shrinkage, what is the reason that the plate loses capacity? Is the spongy lead still there in its original condition or is that changed?

MR. SALOM: The reason it loses capacity is because it is not in good contact mechanically and electrically with the grid. You see, a plate like that sample cannot have any capacity at all, although there is quite a considerable amount of sponge in the receptacles still. Of course, the amount of shrinkage is emphasized by taking the plate out of the battery and drying it. This plate, when it came from the battery, would have shown a loose, non-coherent mass, something like wet ashes.

MR. BENTLEY: I have noticed in the ordinary negative plates in which shrinkage has taken place that usually the pellet adheres very firmly to one portion of the grid. There are cases sometimes when the pellet will be loose and all contact lost. I have seen other cases in which it still adhered firmly to the grid and yet showed a considerable loss of capacity.

MR. SALOM: This is probably in cases where the battery has not been properly treated or has been badly sulphated.

MR. BENTLEY: It is the general practice in making the regular pasted negatives to add a certain amount of some sort of inert material to the plate to overcome the shrinkage, and it does do that to a considerable extent, as shown by the behavior of the box negative of the Electric Storage Battery Company, for instance, in which there is an excess of that sort of material added, while the amount of paste or the actual amount of spongy lead present is practically only that required for the ordinary discharge of the battery and in which the plate maintains its capacity throughout a very considerable life.

Now, I should like to ask further what Mr. Salom knows about the number of cycles that a negative of this sort (the type he is describing) will stand before it disintegrates or loses capacity below its rating; and, further, what is the capacity of a plate in ampere hours per ounce of active material?

MR. SALOM: In answer to your first question, we do not know what the life of our negative plate will be. I have been told by experts of the Planté type that there was every reason to

suppose our negative would last as long as the best Planté negative, or about 10 years. The reason for this is clearly due to the fact that we have a plate filled with spongy lead in the desired condition. In regard to your other question, the capacity of the plate per ounce of active material is about 2 ampere hours, that is to say, ½ ounce is equivalent to one ampere hour. This is about four times as much as the theoretical amount of spongy lead required for an ampere hour. Theoretically it required 0.135 ounces per ampere hour, and four times this, you see, would be 0.54 ounces.

Mr. Bentley: That is about what is obtained in the usual plate.

Mr. Salom: But we obtain a greater capacity in our plates of the same size. I do not say of the same weight. We have 25 percent more active material in the form of spongy lead in the same space and consequently do get a greater ampere-hour capacity. The necessity of having four times as much active material in the plate as the theoretical conditions require is probably due to the low conductivity of the mass after a certain amount of sulphation has taken place. After it has been sulphated to a certain extent and the plates have reached a difference of potential of about 1.8 volts, a further discharge at high rates causes the voltage to drop almost to zero, yet there is still a considerable amount of lead and peroxide in the plates.

Mr. W. C. Bower: What is the usual material they put in that spongy lead?

Mr. Salom: They put in ground pumice stone and graphite.

Mr. Bower: Will not graphite and carbon, having a difference in potentials, produce action?

Mr. Salom: I do not know. They also use flour, sugar and gum arabic. All of these substances have been used with a view of trying to stop the shrinkage and at the same time hold the material in the grid.

I would like to state further that up to the present time my company has only manufactured two general types of plates. The small type for sparking and lighting gasoline automobiles, and the large type for electric vehicles. Of the electric vehicle type there are three different sizes which are used for practically the same purpose; there ought never to have been but one, and

of these three sizes there are three thicknesses of plates, so it makes nine varieties in all. There is no necessity for more than one type.

Mr. Hering: Mr. Sperry brought up the question of the weight per horse-power hour. It seems to me, however, that such a figure is not sufficient to judge a storage battery by, as its life must also be taken into consideration. Storage batteries are somewhat like incandescent lamps in a certain respect. In the early days of the incandescent electric lamps, much stress was laid on the light given out per watt, regardless of the life of the lamp. Now it is well known that you can make an incandescent lamp very efficient if you are willing to let it have a short life, and vice-versa. It seems to me that it is exactly the same with storage batteries. Some seventeen years ago I read a paper showing how to calculate what the most economical life of an incandescent lamp was, so that at the end of that life it would pay better to actually break that lamp and throw it away, even though it was still capable of burning, and for that reason this was properly called the "smashing point" of the lamp.

It seems to me that quite a similar calculation should be made with storage batteries in order to determine their proper and most economical life; this depends not only on its efficiency and on its depreciation, but also on the cost of the original battery and its value as scrap.

I was therefore very much pleased to hear Mr. Salom say that he approved of a shorter life and a lower price. Some fifteen years ago, in a discussion before the American Institute of Electrical Engineers, I suggested that a storage battery with short life, made lighter and cheaper, might be commercially better than one with a long life and made heavier.

Dr. J. W. Richards: That might also be called the "Oslerizing" point of the battery.

Mr. Hepburn: In reference to Mr. Sperry's point of a horse-power for each 80 pounds, we find that with our plates we can bring this down as low as 62 pounds.

In reply to the question asked about the pellets becoming loose in the negative plates and as to how we account for them losing capacity, if the pellet shrinks, it is possibly holding contact on

one or two sides only, and this causes the resistance of the pellet to rise; this decreases the capacity of the pellet, due to improper contact, because it has not the same contact support in connection with the grid that it had originally. If there is any side of this pellet broken away from the grid, the efficiency is decreased, and if the pellet is connected and badly shrunk, you will find that the negative plate made by the pasted method is *short in capacity,* due to the change in the physical condition of the sponge after contracting; whereas with the initially formed negative the physical condition of the sponge does not change, which increases the life and maintains the capacity of the plate indefinitely, and the contact support is perfect at all points.

The spongy lead in the box negative is produced by the same method as it is in the pasted negative of the grid type, namely, by applying litharge in the form of a paste, paint or cement, and makes the box negative subject to the same shrinkage as the pasted grid negative, and also subject to the same loss of capacity, due to the loss of contact by shrinkage, which reduces the efficiency of the cells. The physical condition of the spongy lead made by reducing litharge in a grid is entirely different from the physical condition of the spongy lead produced and used in the initially formed negative, and no shrinkage takes place.

As to the number of cycles the pasted negative plate will stand, let us inquire what it is that reduces the capacity of the plate made by this process. In the first place, it is due to shrinkage; in the second place, to the condition of the sponge, which will lose in capacity after a given time; third, to the contact which it loses by shrinking away from the grid support. In the initially formed negative there is no shrinkage, as the physical condition of the sponge is perfect, and no capacity is lost by continual use; and as there is no shrinkage, there is no loss of contact and the life of the negative plate is absolutely indefinite; it should last longer than the Planté plate because it has an antimonial lead grid to support it.

Mr. W. T. Holmes: I would like to find out if this battery has any greater life under a very heavy discharge.

Mr. Salom: In answer to that question I would say that we have had cases where batteries have been badly treated and where the ordinary battery would have been entirely destroyed,

especially in the negative plate, and yet we have been able to recover the negatives again without any difficulty, practically as good as new. One of the most important factors in handling batteries is not to raise the temperature too high. In cases of neglect, where men have not been paying attention to their duties and the temperature has risen away up above the danger point and the battery has received a serious overcharge, such neglect is comparatively fatal to the positive pasted plate, and in most cases to the negative pasted plate. We have had no trouble in getting our negative plates back again after such bad treatment. I think Mr. Hepburn can give you more information about this matter because he has had the management of the batteries immediately under his control.

Mr. W. Bentley (*Communicated*): Mr. Salom's paper seems to indicate that the shrinkage of negative active material is not accompanied by any change in the nature of that material, and that the only reason for loss of capacity is loss of conductivity by the mass. This is very interesting, if true, but there is no proof adduced to show that this is the case. Inasmuch as it has been held generally that the shrinkage is accompanied by a physical change in the spongy lead, bringing it back partially to ordinary metallic lead, it would seem that evidence should be presented to support the new idea.

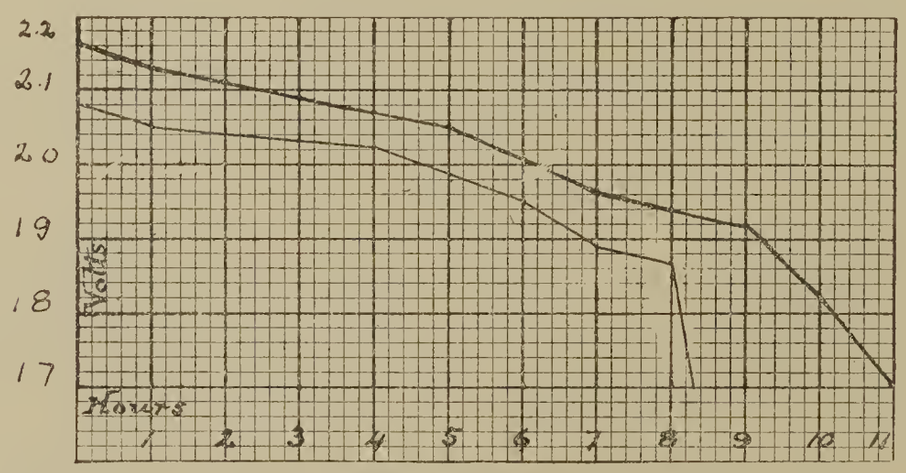
It is well known that durability in Planté negative plates is attained by having their initial capacity enormously greater than that required for active service in the battery, thus allowing for the loss of a great percentage of this capacity with accompanying shrinkage.

The method presented in the paper under discussion would seem to approximate the same idea, by putting into a plate of given size a considerably greater quantity of spongy lead than would be attained by the usual process of pasting unformed oxides. This mass would, of course, be denser than the usual spongy lead, and the diffusion of acid through it ought, therefore, to be more difficult, accompanied by greater concentration changes. If, as has been believed and indicated by experiment, concentration change is one of the chief causes for the deterioration of negative active material, the question arises whether, even with the less percentage of total active material in use on each

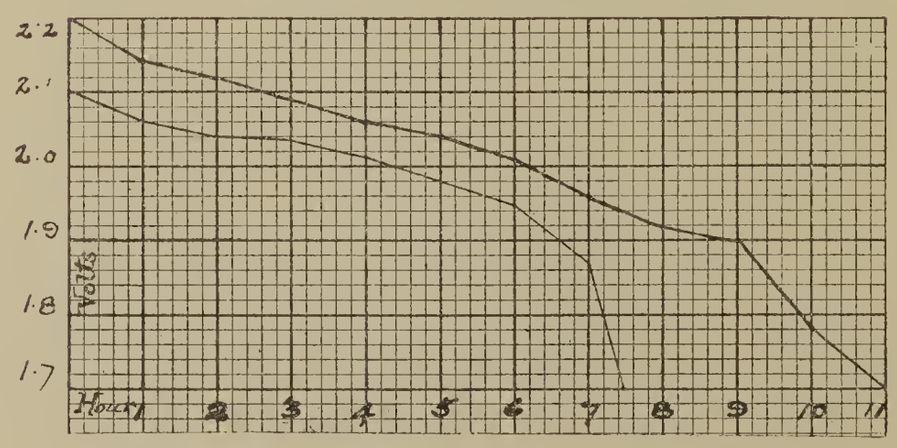
discharge of the denser plate, it would not tend to wear out faster than a more porous plate.

It would be of great interest to know, from experiment, that the shrinkage does not take place in the negative plate in question packed with spongy lead, even if it is not as visible as in the ordinary plate, and, further, at what rate the actual (not rated) capacity of such a plate decreases with continued service.

Mr. Salom (*Communicated*): I append curves showing records of comparative tests of a "Salom" battery with one of similar size and rated capacity, made by one of the best makers of pasted type cells. These batteries consisted of the same number of plates of exactly the same size, they were placed in series, charged together, and the tests made in every respect under identical conditions. Curve 1 shows the "Salom" battery running 11 hours at a 4-ampere rate, or 44 ampere hours; the other battery 8 hours 15 minutes, at the same rate, or 33 ampere hours. Curve 2 shows the same output as before for the "Salom" cell; and 7 hours 30 minutes, or 30 ampere hours, for the other battery.



Curve 1: First discharge, upper line the "Salom" cell.



Curve 2: Second discharge, upper line the "Salom" cell.

A paper read by Mr. Carl Hering, at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, Ill., October 14, 1910, President W. H. Walker in the Chair.

THE SELF DISCHARGE OF PLANTÉ AND FAURE STORAGE BATTERIES.

By O. W. Brown and W. G. Bowers.

Years of experience of the manufacturers and users of storage batteries have proved beyond a doubt that a battery must be designed to meet the special conditions under which it is to be used. Past experience has shown that a Planté cell, while not adapted to electric vehicle service, is the most practical cell for central stations, in which the battery is discharged and charged once a day or more often. Constant re-charge of Planté positive plates serves to keep them in ideal condition, while Faure cells last much longer when not subjected to constant charge and discharge. The fact that good batteries of the Faure type are used for ignition purposes on gasoline automobiles for periods of two to three months before receiving a re-charge makes it appear that batteries of this type are not injured by leaving for considerable periods in a partially discharged condition. The Faure type of lead storage battery is almost universally used for electric vehicle service, because it yields more energy per unit weight than the Planté cell.

An examination of the catalogues of the various storage battery makers shows that almost all of the present-day ignition batteries, and many batteries designed for railway signal service and other intermittent work, where the cells may need to stand for several weeks before receiving a re-charge, are of the Faure type. It has been claimed that the pasted type of plate is best adapted to intermittent service, because when allowed to stand on open circuit it holds its charge for considerable periods, while the Planté cell soon loses its charge and suffers permanent injury. It has been suggested that when a Planté cell is on open circuit, the electrolyte penetrates the thin layer of lead peroxide on the positive plate, and on coming into contact with both the lead grid and active material, causes local action to be set up, forming a layer of sulphate between the grid and lead peroxide active

material. If the cell is allowed to remain very long before receiving a re-charge, the layer of sulphate becomes dense and is difficult to convert into lead peroxide on charge. During re-charge, gas forms on the surface of the lead grid, back of the layers of lead sulphate and active material, causing both to peel from the plates, thus permanently reducing their capacity.

It has also been claimed that the construction of the modern pasted plate is such that, if made from pure materials, it will not be permanently injured when allowed to stand in a charged or partially discharged condition.. This property, if really possessed by the pasted type of plate, is of greater importance than its lightness in weight, when batteries are used for railway signal service, ignition of internal combustion engines, and all intermittent work.

The growing use of storage batteries in low-voltage isolated lighting plants induced the writers to carry out some tests that would aid in determining how far the claims concerning the self-discharge of the Planté and Faure types of cell are borne out by actual test. The behavior of a battery on open circuit is most important in this service, because the successful isolated lighting plant battery must hold its charge when left on open circuit, and should not be permanently injured by an intermittent discharge covering periods of a week to a month or more. Although some manufacturers are recommending a battery for this work which must be re-charged every two or three days, no one can afford to take the time to give a house lighting battery such frequent attention.

Elements manufactured by four different makers were chosen for the tests herein described. Each was assembled with wooden separators, in a glass jar, and given the initial charge recommended by its manufacturer. Each element contained two positive and three negative plates about 20 centimeters (7¾ inches) square. The plates used in the four elements were of different thickness and weight. *Both the positive and negative* plates in Cell No. 1 were 1 cm. (⅜ inch) thick, and of the *pasted type.* Cell No. 2 contained rather light weight Planté plates, not very deeply formed. The positive and negative Planté plates in Cell No. 3 were heavier and also seemed *more deeply formed* than the plates in No. 2. The grids for plate in both Cells No. 2 and

No. 3 were made from pure rolled lead, which, in order to increase the surface, had been grooved by mechanical means. Cell No. 4 contained pasted *box-grid negatives* and *Planté positive* plates. The specific gravity of the electrolyte was 1.210 when the cells were fully charged. When filled to about 1.2 cm. (½ inch) above the upper edge of the plates, the electrolyte in Cells No. 1, 2, 3 and 4 weighed respectively 6.4, 5.6, 5.0 and 6.8 kilograms (14, 12, 11 and 15 pounds). Cell No. 1 was listed by the manufacturer at 100, and each of the other three at 80 ampere hours. In all tests considered in this paper, each cell was considered fully discharged when its total potential reached 1.8 while discharging. Cadmium readings on both positive and negative groups were also taken. (When the positive terminal of the voltmeter is connected to the plate which is being tested, the cadmium reading is marked +.) The cells were usually started charging at a 25-ampere rate, but the charge was finished at a 10-ampere rate in every instance. After the initial charge of Cells No. 2, 3 and 4 was completed, they were allowed to remain on open circuit for a few days, when they were given a slight additional charge, and then discharged at a 10-ampere rate. Cells No. 2, 3 and 4 gave, respectively, 77, 96 and 86 ampere hours. After discharge, the cells were immediately re-charged. During the sixty days following the initial charge of Cells Nos. 2, 3 and 4, they were given only about six discharges. Cell No. 1 was then installed, and after its first discharge, the four elements were subjected to the three tests described in Table I.

TABLE I.

Discharge Rate Amperes	Cells stood after Charge, before Discharge	Temp. Degrees C.	Capacity in Ampere Hours			
			Cell No. 1	Cell No. 2	Cell No. 3	Cell No. 4
10	Four days	20	110	75	87	75
10	Over night	18	112½	70	87½	77½
10	Over night	19	112½	71¾	85	75

The tests recorded in Table I were completed on February 9, 1910. Immediately following these tests, the four cells were placed in series with others and used for laboratory work. By the last week in June they had been partially or completely

discharged and re-charged about forty times. In order to put them in the best possible condition, they were given four discharges, followed by slight over-charges. The cells were then given eight careful charges and discharges, under the conditions described below. In order that the four cells should receive as nearly as possible like treatment, they were discharged in series, each being thrown in circuit at the beginning and cut out at the end of its charge and discharge.

It is almost impossible to run a series of storage battery tests covering several months under conditions which are comparable in every respect. The tests recorded in this paper are not comparable in some particulars; however, certain conclusions, not affected by any variation in the conditions, are obvious to anyone examining the data.

Table II contains the results of the eight tests.

The current efficiencies given in the table (p. 73) are calculated in each instance from the discharge and the charge following. The current efficiency of Cell No. 1, on every test, was slightly higher than that of the other cells. This is partially explained by the fact that all were discharged at the same current strength, although No. 1 possessed a greater capacity than the other cells and should on this account stand a higher discharge rate.

We may safely take the average of the three discharges of each cell given in Table I as representing the actual capacity of the cells when first installed. All of the cells would have shown greater capacity on the early discharges if the tests recorded in Table I had been carried out when the temperature was higher than 18° to 20° C. As is well known, one degree rise in temperature often increases the capacity of a battery 1 to 2 percent.

The average capacity of the discharges of each cell shown in Table I and the average of the 49th and 51st discharge are tabulated below.

	Discharge Rate, Amperes	Capacity in Ampere Hours Cell No. 1	Cell No. 2	Cell No. 3	Cell No. 4
Average of discharges in table I	10	111.66	72.25	86.5	75.8
Average of the 49th and 51st discharge	10	131.25	66.83	75.0	73.75
Loss or gain of capacity during the first 50 discharges.	..	17.59% Gain	7.5% Loss	13.3% Loss	2.7% Loss

TABLE II.

Number of Discharge	Discharge Rate, Amperes	Cells on open Circuit before Starting Discharge	Temperature in Cell at End of Discharge—C°	Cell No. 1 Faure Positive Faure Negative			Cell No. 2 Planté Positive Planté Negative			Cell No. 3 Planté Positive Planté Negative			Cell No. 4 Planté Positive Faure Negative		
				Output Ampere Hours	Input Ampere Hours	Current Efficiency Percent	Output Ampere Hours	Input Ampere Hours	Current Efficiency Percent	Output Ampere Hours	Input Ampere Hours	Current Efficiency Percent	Output Ampere Hours	Input Ampere Hours	Current Efficiency Percent
44	15	4 days	25°	112.5	120		67.5	77.5		78.75	92.5		70	77.5	
					125	90		80	84.5		92.5	85.11		80.0	87.5
45	15	8 days	28°	108.75			63.75			75.00			67.5		
					135	80.55		80	79.69		93.3	80.36		87.5	77.15
46	15	Over night	30°-31°	112.5			63.75			75.00			67.5		
					126.66	88.82		73.3	86.93		87.5	85.71		80.0	84.38
47	15	12 days	27°	111.25			57.5			68.75			63.75		
					130	85.58		73.3	78.39		85.0	80.88		80.0	79.7
48	15	1 hour	29°	120			60.			78.75			67.5		
					130	92.3		70	85.7		85.83	91.75		75.0	90.0
49	10	1 hour	25°-27°	129.17			66.66			76.66			72.5		
					140.85	91.72		75.5	88.29		87.5	87.61		82.0	88.42
50	10	20 days	26°-27°	129.17			56.66			67.5			64.17		
					160	80.73		82.5	68.68		90.0	75.0		90.0	71.3
51	10	At once	25°	133.3			67			75.3			75.0		

As the temperature during the 49th and 50th discharges was about 6° C. higher than at the time of the first discharges, given in Table I, the capacity should have increased 6 to 10 percent on account of change of temperature. However, Cell No. 1, containing both positive and negative plates of the Faure type, was the only one that possessed as high a capacity on the 50th discharge as on the first three or four discharges. This cell gained 17.59 percent in capacity, while Cells No. 2 and 3, which contained Planté positive and negative plates, lost 7.5 percent and 13.3 percent, respectively. In Cell No. 4, containing Planté positive and pasted negative plates, the loss was only 2.7 percent, indicating that periods of rest are more harmful to Planté negatives than to Planté positives. Had Cells Nos. 1 to 4 been given a charge and re-charge every day after being assembled, they would all have gained in capacity; however, it is seen that the Planté type of plate continually decreases in capacity and suffers permanent injury when allowed to remain on open circuit for considerable periods.

The loss on eight and twelve days' standing over that which is suffered when the cell stands only over night before discharge may be seen by comparing discharge No. 46 with 45 and 47. The losses in each cell, calculated on this basis, are given below.

Stood on open circuit before discharge	Loss of capacity on standing on open circuit before discharging			
	Cell No. 1 % loss	Cell No. 2 % loss	Cell No. 3 % loss	Cell No. 4 % loss
Eight days	3.33	5.55	4.3	3.57
Twelve days	1.11	9.8	8.33	4.8
Average loss on the two tests	2.22	7.67	6.31	4.18

On both the eight and twelve days' standing, it is seen that Cell No. 2, which contained Planté plates having rather thin coatings of active material, suffered the greater loss. The loss of capacity on standing in Cell No. 3, having more deeply formed Planté plates, is a little less than in No. 2. The average loss in Cell No. 4, containing pasted negative and Planté positive plates, is 4.18 percent, or 40 percent less than where both negative and positive plates are of the Planté type. Cell No. 1, containing both positive and negative plates of the Faure or pasted type, suffers least from self-discharge. The average loss on the two tests given above is only 2.22 percent, or less than one-third of that suffered by the cells containing Planté plates only.

A comparison of discharges 49 and 50, made at a 10-ampere rate, shows in even a more marked manner the difference in the behavior of Planté and Faure plates when allowed to remain on open circuit.

From these tests it is seen that Cell No. 1 suffered no loss when allowed to stand twenty days on open circuit, while the losses in Cells 2, 3 and 4 were 15 percent, 11.94 percent and 11.84 percent, respectively, after remaining for twenty days on open circuit. Some loss in Cell No. 1 would be expected. However, this cell, at this stage of its life, seems to be increasing in capacity on each succeeding discharge at such a rate that any anticipated loss is entirely hidden.

Conclusions.

The data given in this paper show that the Planté type of cell loses its charge when allowed to remain on open circuit for periods of ten to twenty days. The Faure cell, when made from pure materials, suffers only very slight loss in capacity when left on open circuit. In every test, the self-discharge of the Faure cell was much less than cells of the Planté type.

The data also show that the Planté cell suffers permanent injury when considerable periods of time are allowed to elapse between charges; while one or two re-charges of a Faure cell restores it to its original capacity.

In the light of these results, the Faure type of cell is best suited for all service where intervals of a week to a month or more must elapse between charges. This condition is found in some telephone plants, in isolated lighting plants, and where cells are used for ignition purposes and for the operation of signal systems.

Electrochemical Laboratory,
Indiana University.

DISCUSSION.

Mr. E. A. Sperry: I wish someone here, if they know the present capacity of the far-famed Edison cell, would give us a

similar figure for this. Some of the tests that I knew of, made three years ago, brought this cell something like 110 pounds per electrical horse-power hour.

Mr. Pedro G. Salom: The Edison cell, according to their latest circular matter, shows that their type 6A, with a weight of 19.2 pounds, has a capacity of 45 amperes for 5 hours, or 225 ampere hours, with an average voltage of 1.2. This would equal 270 watt hours, or 14 watts per pound, or 53 pounds per electrical horse-power hour. This weight includes the retaining jars and everything on the battery complete. Our type 9 L. V. has a capacity of 24 amperes for 5 hours, or 120 ampere hours at 2 volts, or 240 watt hours, and weighs 22 pounds complete, and is therefore equivalent to nearly 11 watts per pound or, say, 68 pounds per electrical horse-power hour; therefore you see they have a slight advantage over the lead battery in capacity pound for pound, as we do not claim over 11 watts per pound of complete battery including the electrolyte. Our jars are much heavier and there is a greater amount of electrolyte. The separators are also heavier in our battery than in the Edison. The Edison jar is a very thin sheet of steel, nickel plated, and the whole is really a beautiful piece of apparatus; but the claim that they make of 100 percent greater capacity pound for pound is not correct, that is, it is not correct compared with what we are doing. It may be correct for some of the comparisons they have made with other batteries.

Mr. D. M. Hepburn: In reference to the capacity of the Planté plate being reduced by standing, it is easily understood when you consider the Planté negative has not as large an amount of spongy lead to do its work, and it is due to the enormous surface which it has in proportion to active material. In the pasted plate the excess of spongy lead runs sometimes as high as 50 percent, or, in other words, when the positive is discharged, there is enough of negative material left in the pasted plate to handle practically 40 to 50 percent more positive, and a similar amount of shrinkage as in the pasted negative would not be so serious as the same amount in the Planté, in affecting the capacity.

Mr. Edward Gudeman: There is one consideration of the storage battery that seems to be left out always. Instead of

giving only the power and weight, we ought to give the power both per unit of weight and per unit of volume, that is, give the power per space occupied. With stationary storage batteries the weight is often a minor consideration, as one can build the foundation to carry a large weight; but when you come to use a storage battery in a moving vehicle, the space occupied is often of greater importance than the weight itself. In comparing efficiency of batteries this is a consideration of importance.

Mr. Hepburn: In giving the efficiency of the battery we have used a 4-hour discharge rate. As you say, the weight is a minor consideration, and we can show a greater battery efficiency by giving it a discharge at an 8 or 10-hour rate, which would increase the amount of current practically 30 percent for a 10-hour discharge rate over a 4-hour rate and will show a considerable saving in weight per horse-power by this method. The higher rate of discharge you use on a given battery the more you reduce its efficiency per pound.

Mr. ———: I would like to ask if there is not a much greater reduction in capacity in changing from a 10-hour rate to a 4 or 5-hour rate than is ordinarily shown?

Mr. Hepburn: There is practically about 25 percent difference in efficiency between the 8-hour rate and the 4-hour rate of discharge.

A paper read by title at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, Ill., October 14, 1910; President Wm. H. Walker in the Chair.

A NEW SECONDARY CELL.

By David J. Block.

It is a well-known fact that on electrolysis of the halogen salts of zinc, cadmium, cobalt, nickel, iron, tin or copper, the metal is deposited at the cathode and the halogen at the anode, but no attempt appears ever to have been made to recombine these elements so as to recover as kinetic energy, the potentiality endowed by their electrolytic dissociation. The cell herein described, is designed to retain or store the halogen so eliminated, within the body of the anode and to secure such an ionic emplacement as will, by recombination, return approximately all of the energy used in effecting dissociation.

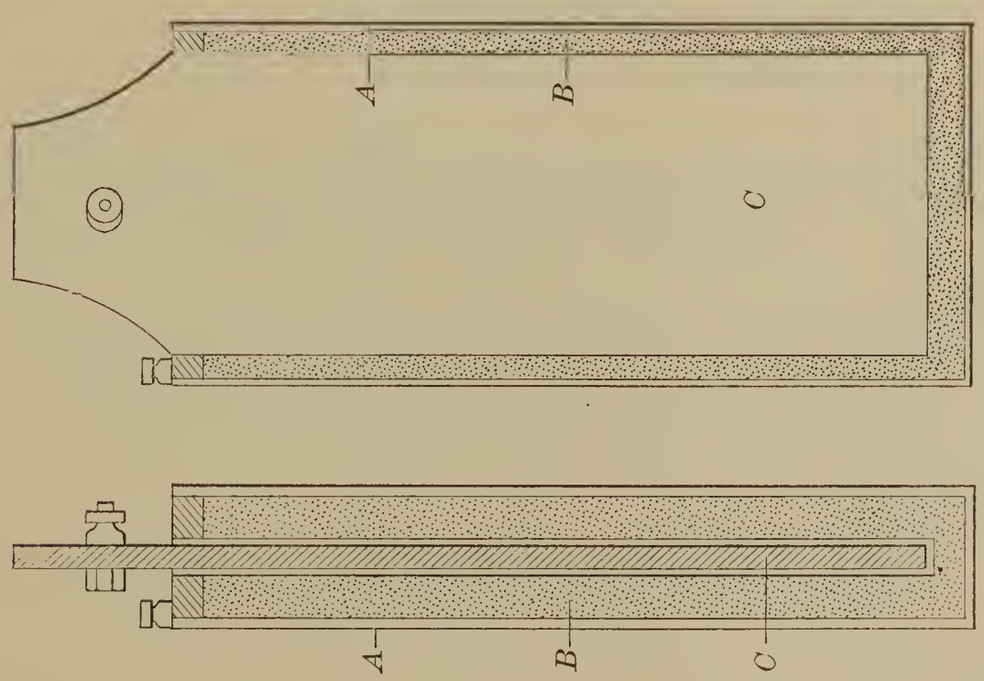


Fig. 1.

The cell consists essentially of a zinc containing jar "A," which serves as the cathode element; a paste "B" of ground or granular carbon impregnated with an aqueous solution of ferric hydroxide, zinc bromide and zinc chloride; and an anode of porous

carbon, "C," surrounded with cloth asbestos, the purpose being to form a carbonaceous wick to support bromine against gravity, and to condense chlorine. This is accomplished by using, in addition to the asbestos cloth, a specially prepared form of charcoal, which is able to retain within its pores about 200 times its volume (¾ of its weight) of chlorine gas and a larger quantity of liquid bromine.

The mechanism of reaction is as follows:

$$\overbrace{15ZnCl_2 + 3ZnBr_2 + 18H_2O + 12Fe(OH)_3}^{\text{ANODE}} =$$

On Charging

$$18Zn + 12Fe(OH)_3 + 30HCl + 6BrHO_3$$

The ferric hydroxide then neutralizes the bromic and hydrochloric acids, giving ferric bromate and ferric chloride, thus:

$$30HCl + 6BrHO_3 + 12Fe(OH)_3 =$$

On Discharging

$$10FeCl_3 + 2Fe(BrO_3)_3 + 36H_2O.$$

The ferric bromate and the ferric chloride are potentially equal to bromic and hydrochloric acids. The six molecules of bromic acid lose their 18 atoms of oxygen to the 18 atoms of zinc; the bromic acid becomes hydrobromic acid, and the zinc oxide so produced dissolves in the hydrobromic and hydrochloric acids hydrolyzed from their ferric salts, giving back the original chloride and bromide of zinc, without the evolution of hydrogen and polarization, thus:

$$18Zn + 10FeCl_3 + 2Fe(BrO_3)_3 + 36H_2O =$$
$$15ZnCl_2 + 3ZnBr_2 + 12Fe(OH)_3 + 18H_2O.$$

Some ferric chloride, not shown in the equation, is present to hold up the hydroxide and, in addition, a suitable substance is used to increase the conductivity of the electrolyte; neither of these interfere with the mechanism of electrolytic or chemical action, and consequently are omitted from the equation.

The first of these cells constructed had a cathode of iron and an

anode of carbon surrounded with a paste of the haloid salts of iron. This developed surprising voltage irregularities, both on charging and discharging, due to the fact that the halogen salts of iron exist in two modifications. This is true also of tin and copper, so that in the selection of a cathode material for a second cell we were limited to lead, cobalt, nickel, cadmium or zinc. Of these, the latter was selected as best adapted to the purpose, although a cobalt cell is now under construction.

The zinc-carbon type of brom-chlorine accumulator cannot yet be considered a commercial success, the first of these cells having attained an electrical efficiency of but 28 percent. This was largely due to high internal resistance, and has, in a measure, been overcome. One of the newer of these cells, now under test, shows an efficiency of nearly 52 percent. However, this type of secondary cell has many desirable features chief of which, perhaps, is its light weight, the cell herein described developing one actual horse-power hour per 15 pounds weight; the cost is low; no loss of energy due to hydrogen formation at the cathode can occur; and obviously, because of the neutral or weakly basic character of the electrolyte, the charged cell may be placed aside for long periods without loss of energy due to the corrosive action of the electrolyte.

In a future paper I hope to present complete discharge curves for this cell and to give you the results of our investigation of the cobalt accumulator, now under construction.

Research Laboratory,
Applegren & Block,
Chicago, November 5, 1910.

A paper read by title at the Eighteenth General Meeting of the American Electrochemical Society in Chicago, Ill., October 15, 1910; President Wm. H. Walker in the Chair.

ON THE ELECTROLYSIS OF SOME CYANIDES.

By Harrison E. Patten and Wm. Roy Mott.

INTRODUCTION.

In a previous communication[1] to this Society the authors gave single potentials of zinc in normal aqueous solutions of KCN, KCNO, KCNS and $K_4Fe(CN)_6$, and, in addition, the polarization of the total cell when these same solutions were electrolyzed between polished platinum electrodes using low impressed electromotive force. Some of the auxiliary data obtained in this investigation, but not published, suggested the desirability of obtaining anode and cathode single potential polarization values for these same solutions. The present paper gives the values obtained.

Method and Apparatus.

The total cell current — e. m. f. curves were obtained, using the same cell and instruments described in a previous paper.[1] The method of measuring the single potential discharge from anode and cathode is given in other papers.[2]

Results.

Table I gives the current — e. m. f. data for the total cell, using normal aqueous solutions of KCN, KCNO, KCNS and $K_4Fe(CN)_6$ between platinum electrodes. Table II contains the anode and cathode polarization of normal aqueous $K_4Fe(CN)_6$ at polished platinum electrodes for different current densities. Tables III, IV and V give current — e. m. f. data and discharge values for mixtures of KCN with $MgSO_4$, $CdSO_4$ and $CuSO_4$, respectively. And Tables VI and VII show the anode and cathode polarizations of KCNS and of KCNO. The decomposition points given by plotting the data in Table I are: For KCN, 2.7 volts at C. D. .020 ampere,[3] 2.1 volts at C. D. .007 ampere, and

[1] Transactions Am. Electrochem. Soc. **3**, 317 (1903).
[2] Jour. Phys. Chem. **8**, 153 (1904); Trans. Am. Electrochem. Soc. **12**, 334 (1907); *Ibid.* **15**, 523 (1909).
[3] Current density is calculated throughout on a basis of amperes per square centimeter of electrode surface.

TABLE I.

Current e. m. f. curves taken between polished platinum electrodes for aqueous solutions.

KCN, t = 19° c.		$K_4Fe(CN)_6$, t = 25°		KCNO, t = 19°		KCNS, t = 19°	
Volts	Amperes per Sq. Cm.	Volts	Amperes per Sq. Cm.	Volts	Amperes per Sq. Cm.	Volts	Amperes per Sq. Cm.
1.01	0.000013	0.14	0.00002	0.37	0.000010	0.508	0.0000165
2.00	.000033	.28	.00004	0.54	.000032	0.668	.0000534
1.50	.00060	.399	.000067	1.035	.000155	1.270	.00011
		.560	.000080				
2.20	.0023	.670	.00011	1.50	.00034	1.60	.0017
2.50	.0067	.736	.00019	1.90	.00067	1.80	.0067
3.00	.023	.790	.00027	3.00	.036	2.00	.020
3.50	.040	.800	.00040	2.80	.011	2.20	.030
3.80	.093	1.080	.00064	2.60	.007	2.40	.041
3.50	.060	.770	.00041	2.40	.003	2.60	.067
3.25	.0377	1.080	.00014	2.20	.001	2.80	.093
3.00	.0213	.940	.00002			2.60	.065
2.50	.0063	.84	.00000	3.90	.078	2.40	.042
1.65	.0007			3.70	.067	2.20	.030
1.00	.00000			3.40	.041	2.00	.0197
				3.10	.028	1.60	.0023
4.00	.100	1.00	.000	3.00	.021	1.40	.0013
3.60	.0667	1.20	.001	2.50	.004	1.20	.001
3.50	.060	1.40	.0043	2.25	.0013	1.00	.0002
3.40	.050	1.6	.013				
3.30	.0417	1.8	.0277	1.70	.0000		
3.20	.0343	2.0	.0267				
3.10	.0277	2.0	.015				
3.00	.0203	2.5	.0157				
2.90	.0157	3.0	.0193				
2.80	.0127	2.5	.0157				
2.50	.006	2.0	.015				
2.20	.0023	1.5	.007				
1.50	.0003						
		1.4	.0000				
1.00	.0000	1.50	.0083				
		2.00	.0667				
		2.00	.0157				
		2.50	.0157				
		3.00	.019				
		2.50	.0157				
		2.00	.011				
		1.50	.005				
		4.00	.100				
		3.50	.034				
		3.00	.023				
		2.50	.0277				
		2.00	.014				
		1.50	.0067				

1.08 volts at C. D. .003 ampere; for $K_4Fe(CN)_6$, 2.7 volts at C. D. .034 ampere, 2.0 volts at C. D. .027 ampere, and 0.9 volt at C. D. .003 ampere. After the C. D. 0.027 ampere is reached, the counter e. m. f. of polarization reduces the current nearly one-half, and this polarization is maintained by a C. D. of .015 ampere.

TABLE II.

Anode and cathode polarization of normal aqueous $K_4Fe(CN)_6$ at polished platinum electrodes under increasing current density. $t = 18°$ C.

Current Density Amperes Per Sq. Cm.	Polarization Anode Volts (—).	Polarization Cathode. Volts (+).	
0.00067	0.694	0.281	
0.00000	.637	.300	Discharge.
0.0013	.694	.510	
0.006	.713	.623	
0.000	.713	.510	Discharge.
0.012	.867	.682	
0.014	1.229	.740	
0.0123	1.457	.740	
0.000	.808	.490	Discharge.
0.0123	1.554	.758	
0.014	1.973	.788	
0.0167	2.072	.820	
	— 1.134	.490	Discharge

TABLE III.

Anode polarization of normal aqueous KCN, 20 c.c. mixed with 20 c.c. normal $MgSO_4$. $t = 21.5°$ C.

Current Density Amperes Per Sq. Cm.	Impressed E. M. F. Volts.	Polarization Anode Volts (—).
0.0047	1.06	
0.0083	1.8	
0.0134	2.0	
0.0167	2.2	
0.0167	2.6	
0.0167	2.8	
0.0184	2.8	
0.020	3.0	
0.0234	3.5	
0.047	4.0	
0.034	3.5	
0.020	3.0	
0.013	2.5	
0.000	2.0	
		— 1.096 Discharge.

Table IV.

Anode and cathode polarization of normal aqueous KCN, 20 c.c. mixed with 20 c.c. of normal $CdSO_4$, under increasing current density. $t = 21.5°$ C.

Current Density Amperes Per Sq. Cm.	Polarization. Anode Volts (—).	Polarization. Cathode Volts (+).	E. M. F. Impressed Volts.
0.00067	0.667	0.910	1.6
0.0013	0.988	0.940	1.8
0.002	1.082	0.94	2.02
0.0034			2.2
0.010			2.4
0.0174			2.6
0.027			2.8
0.040			3.0
0.025			2.8
0.016			2.6
0.008			2.4
0.0034			2.2
0.003			2.0
0.0083			2.4
	—.962	.832 Discharge.	

Table V.

Anode and cathode polarization of normal aqueous KCN, 20 c.c. mixed with 10 c.c. normal $CuSO_4$, at polished platinum electrodes, under increasing current density $t = 21.5°$ C.

Current Density Amperes Per Sq. Cm.	Polarization. Anode Volts (—).	Polarization. Cathode Volts (+).	
0.002	—0.855	0.551	
.0027	.895	.671	Tiny gas bubbles from cathode.
.000	.827	.524	Discharge.
.004	.993	.780	
.0027	1.257	.700	Good deposit of copper.
.0027	1.490	.711	
.0037	1.604	.780	
.0063	1.631	.872	
.0077	1.820	.912	
.0097	2.005	.940	
	—1.096	.619	Discharge.

TABLE VI.

Anode and cathode polarization of normal aqueous KCNS at polished platinum electrodes, under increasing current density. $t = 25°$ C.

Current Density Amperes Per Sq. Cm.	Polarization. Anode Volts (—).	Polarization. Cathode Volts (+).
0.0027	0.960	0.583
.0127	1.012	.716
.030	1.066	.862
.053	1.127	.970
.000	—.986	.533 Discharge.

TABLE VII.

Anode and cathode polarization of normal aqueous KCNO at polished platinum electrodes, under increasing current density. $t = 25°$ C.

Current Density Amperes Per Sq. Cm.	Polarization. Anode Volts (—).	Polarization. Cathode Volts (+).
0.00067	1.160	0.425
.0013	1.565	0.450
.0023	1.664	0.517
.0000	1.399	0.412 Discharge.
.0107	1.890	0.636
.0000	1.411	0.412 Discharge.

KCNO gives a decomposition point of 2.7 volts at a C. D. of .011 ampere; and another, 1.7 volts at a C. D. of .0003 ampere. KCNS shows a decomposition point at 1.7 volts for a C. D. of .025 ampere; and another at 0.9 volt for a C. D. of 0.001 ampere.

The anode and cathode polarizations for $K_4Fe(CN)_6$ given in Table II are plotted in Plate I; ordinates are in volts, single potential; abscissas are in amperes per sq. cm. The polarization effect observed at a C. D. of 0.027 ampere in the decomposition curve for the total cell recorded in Table I is now seen in Plate I to be mainly in evidence at the anode; the single potential here being —1.23 volts, which, with the cathode single potential, +0.74 volt, gives +1.97 volts as the polarization of the whole cell—a close duplication of the decomposition point given in

Table I. The points given by triangles are permanent polarizations, whereas the other points in Plate 1 are instantaneous discharge potentials.

The anode discharge, —1.096 volts for KCN + $MgSO_4$, given in Table III, is close to that for $K_4Fe(CN)_6$. In this connection consider the anode polarizations given in Tables

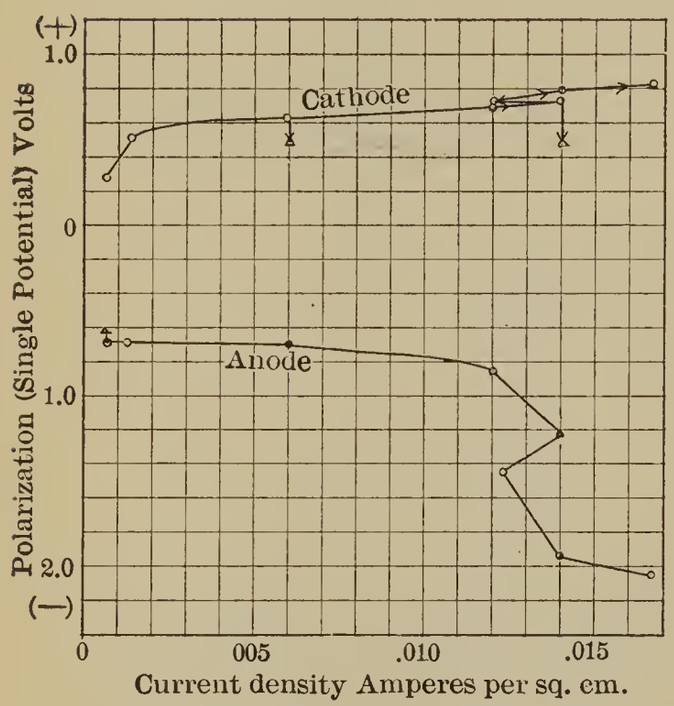


Plate 1.—Electrolysis of $K_4Fe(CN)_6$.

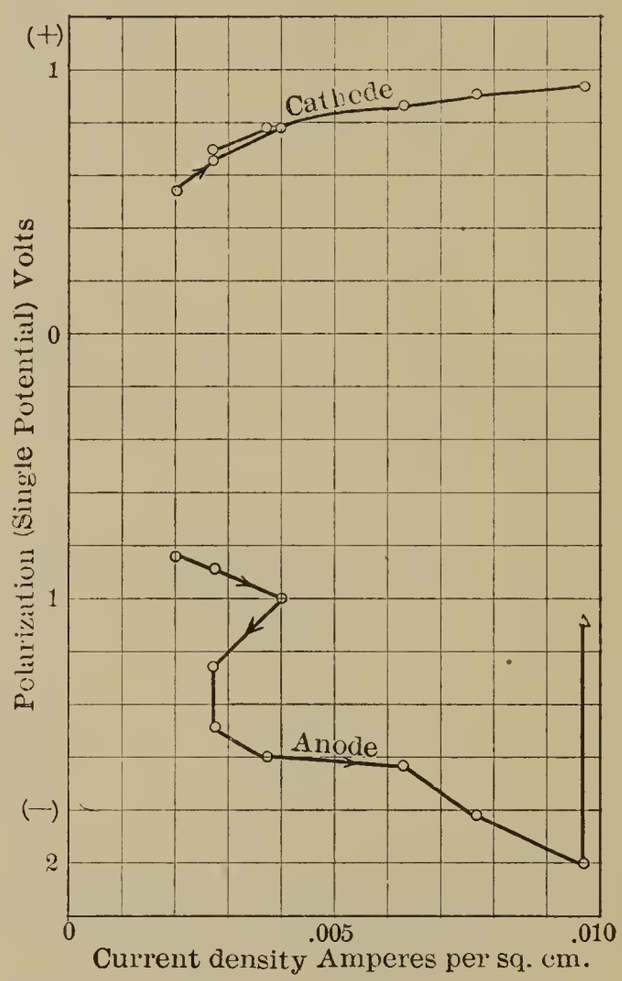


Plate 2.—Electrolysis of KCN + $CuSO_4$.

VI and VII and plotted in Plates 3 and 4: The polarization at the anode is KCNO. Plate 4 is —1.40 volts at all current densities between .0023 and .0107. Now this value, —1.40 volts, is the oxygen potential. Evidently the oxygen evolved does not appreciably react with the KCNO, and establishes its own single potential. This agrees with the experiment of Paterno and Pannain,[4] who oxidized KCN to KCNO and obtained a yield 90 percent of the theoretical. The similarity of the anode polarization of $K_4Fe(CN)_6$, Plate 1, in magnitude and

[4] Gaz. chim. ital. 34, II, 152-155 (1904).

sign to that of KCN + $CuSO_4$, Plate 2, indicates a similar reaction, which probably is the formation of KCNO, together with per — salts. The anode polarization for KCNS, Plate 3, lies higher (less negative) than that for $K_4Fe(CN)_6$, or KCN + $CuSO_4$, and is even above the potential of oxygen, exhibited by the anode in KCNO solutions. The reduction at the cathode is

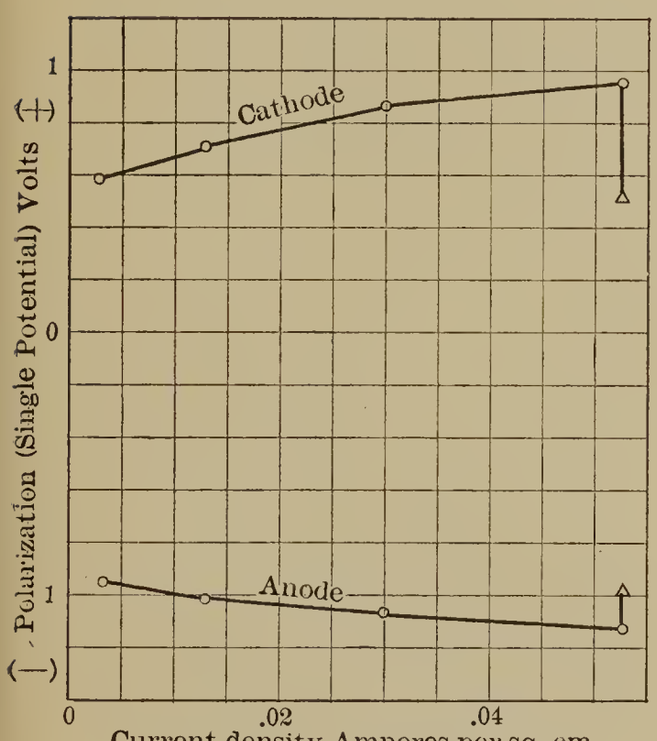


Plate 3.—Electroylsis of KCNS.

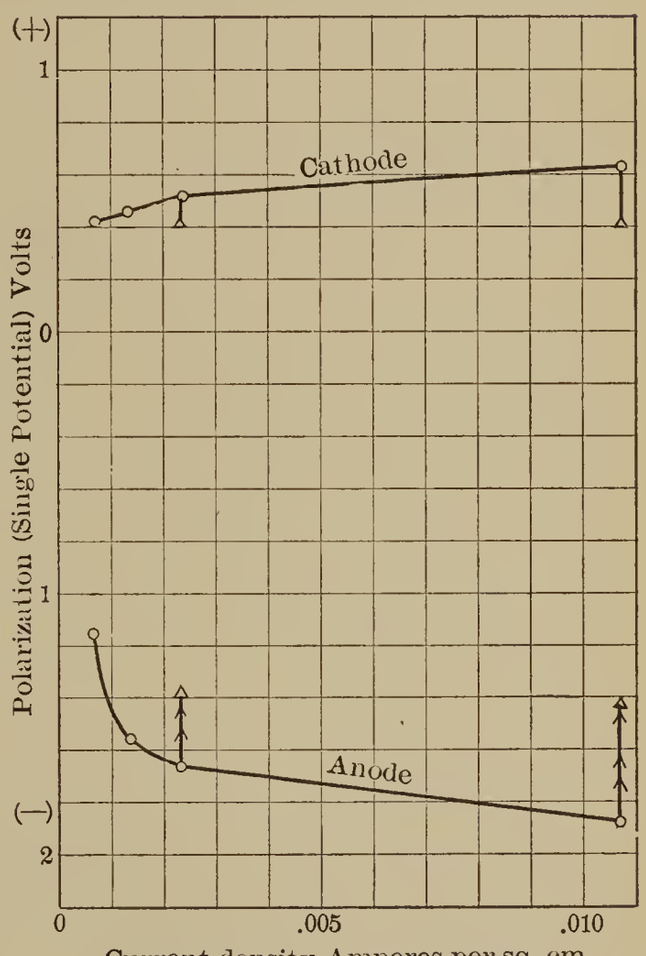


Plate 4.—Electrolysis of KCNO.

only slightly in evidence, even in KCNO solution, as shown by the cathode polarizations which are all near +0.5 volt, the value of hydrogen in alkaline solution.

This work was done in the laboratory of applied electrochemistry at the University of Wisconsin. The authors express their appreciation of the courtesy extended to them by Prof. C. F. Burgess.

A paper read at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, Ill., October 14, 1910, President W. H. Walker in the Chair.

SOME PRACTICAL APPLICATIONS OF OVERVOLTAGE PHENOMENA.

By Carl Hambuechen.

To the electrochemical student the term "overvoltage" signifies that value of electrochemical potential set up by hydrogen while being liberated upon a cathode, which is in excess of the value which hydrogen ought to give.

That hydrogen while being liberated does not behave in a simple, straightforward manner is definitely known, while the reasons for its peculiar behavior are still matters of speculation.

Electrochemical text books tell us that various elements, including the metals and hydrogen, when placed in contact with an electrolyte set up an electrochemical potential at such surface of contact, this electrochemical potential being dependent upon the electrolyte, as to its composition and temperature, and upon the metallic element itself.

Hydrogen, being a gas, and practically non-conductive, cannot be employed conveniently as an electrode, and the manner in which its potential can be measured is to coat a metal electrode with it and measure such electrode potential. As carried out in the laboratory, platinum is employed as the electrode to be coated with hydrogen, and the coating process consists in depositing hydrogen continuously from an electrolyte by the passage of an electric current.

Platinum is chosen advisedly because it is upon this metal that the hydrogen is most easily deposited, and because platinum is less likely than most other metals to be attacked by the electrolyte and thus be the cause of troublesome secondary reactions.

It is known that hydrogen exhibits a greater willingness to be thrown out of an electrolyte on a platinum electrode than it does on most of the other metals. It has a decided aversion to tin, lead and zinc, which is exhibited by the higher voltage required to force its deposition upon them.

It is the purpose to point out in this paper some practical aspects of this overvoltage phenomenon. Mott[1] discusses overvoltage as a factor to be reckoned with in a study of the corrosion of metals. He gives the following as calculated values of overvoltage of hydrogen on the various metals:

Tin	+ 0.55 Volts
Lead	0.50 "
Antimony	0.45 "
Bismuth	0.45 "
Gold	0.20 "
Silver	0.15 "
Platinum	0.15 "
Iron	0.10 "
Copper	Reference standard.
Brass	— 0.14 Volts

Neumann, in his table of electrochemical potentials of various metals making contact with electrolytes, gives the following values of elements against normal chloride solutions:

Aluminum	+ 1.015 Volts
Zinc	+ 0.503 "
Cobalt	— 0.015 "
Nickel	— 0.020 "
Tin	— 0.85 "
Iron	— 0.087 "
Lead	— 0.095 "
Hydrogen	— 0.249 "
Bismuth	— 0.315 "
Copper	— 0.5 + "
Platinum	— 1.140 "
Gold	— 1.356 "

According to the generally accepted theory, the corrosion of metals is caused by galvanic couples due to impurities or electronegative elements in the metal under consideration, and the rapidity of corrosion will then be dependent principally upon two factors, the resistance of the local circuits, and the electrochemical voltage of the couple considered as a primary cell. If the electrochemical voltage was the only factor governing the motive force which sets up the current, we could use the Neumann table of single potentials as a guide to tell just how bad certain combinations of metals are from the corrosion standpoint. Thus we would know that zinc containing particles of copper would be subject to corrosion couples of 1.003 volts; zinc with iron, 0.59 volt; zinc with tin, 0.588 volt, etc.

[1]Transactions American Electrochemical Society, **15**, 569, (1909).

Mott pointed out that there is a third and more important factor, namely, the overvoltage values; that the active galvanic couples always give rise to the liberation of hydrogen on the electronegative or cathodic particles, and that it is such overvoltage values that must be considered. Thus, a couple of zinc and copper would have the value approximately as above given, 1.003 volts, because hydrogen on copper has very slight overvoltage; zinc with iron would have not the value 0.59 volt, but 0.1 volt less, or 0.49 volt, effective pressure; and zinc and tin would have 0.588 less 0.55 volt (the overvoltage of tin), or 0.038 volt.

While the electrochemical potential table indicates that tin is as bad an element as is iron for producing corrosion on zinc, the correction for overvoltage shows that tin is far less harmful. And this is borne out by the facts in various practical instances. It is a matter of practical knowledge that iron or copper introduced as an impurity in dry cells is very harmful, producing rapid deterioration, while lead and tin (having high overvoltages) are almost harmless. This is fortunate, as otherwise the solder for making the seams would have to be prevented absolutely from entering the container and making contact with the electrolyte. The dry cell construction would be, therefore, more difficult and expensive.

A well-known household method of cleaning silverware of tarnish consists in placing the silverware in a zinc vessel and covering by an electrolyte, such as baking soda, and salt. The tarnish is removed by electrochemical reduction, the zinc acting as anode and the silver surface as cathode. In studying this process, the writer noticed that a zinc vessel having been used thus a few times lost its effectiveness, owing to the formation of a high resistance film on the zinc surface, which prevented the silverware from making electrical contact therewith when resting upon it.

It was found that a grating of tinned iron wire soldered to the zinc entirely prevented this difficulty. The tin acting as the cathode surface is always maintained bright and chemically clean, and owing to the overvoltage of tin, this is kept clean at the expense of a minimum amount of current. Then when the silverware is placed upon such tinned grating, it cannot avoid being placed in electrical contact, and the current generated by

the dissolving of the zinc is concentrated upon the silver to the practical exclusion of the tin.

In the making of electrical contacts the usefulness of tin is well known, and this is dependent largely upon its high overvoltage.

Zinc is employed extensively as a means of preventing boiler corrosion. It is an old remedy and is effective when properly employed. The principal difficulty in the use of zinc is that it must be attached firmly to the iron or other metal structure it is designed to protect so as to insure electrical contact. The protection is effected at the expense of the zinc, which is corroded and which must be replaced from time to time. It is evident that in the interior of a boiler it is difficult to introduce zinc, and it appears that the overvoltage of tin may be called into play in this connection.

As an example of the various methods in which this might be employed, I may name the following. Through the boiler which is to be protected is passed an iron rod or tube coated with a layer of tin. This rod is bolted to the boiler shell in such a way as to make electrical contact. This tinned tube forms with the iron of the boiler a galvanic couple which would be detrimental to the boiler if it were not for the overvoltage which is set up by hydrogen on the tin. From this tinned rod may be suspended plates or chunks of zinc by means of a tinned stirrup. The exposed tin always acting as a cathode will be kept clean and therefore be capable of making electrical contact. A convenient form in which to employ the zinc is as rings of zinc coated on the inner surface with tin or solder and slipped over the tinned rod. This can be readily provided for by stuffing boxes or hand holes through which the tinned rod is passed. The worn out zinc pieces can be thus removed and new zinc introduced.

Mr. Mott has pointed out the desirability of studying overvoltage of the various metals in connection with the investigation of corrosion phenomena; that an alloy consisting of two elements widely separated in the electrochemical series may not necessarily be a corrodible alloy if the negative element possesses a high overvoltage.

In studying corrosion, we are concerned not only with the

contact potential and the overvoltage of the individual elements constituting an alloy, but the study must be extended to include the single potential and overvoltage of the alloying compounds. Thus, for example, it has been found that brass has an extremely low overvoltage, lower than either the copper or the zinc of which it is composed. This is undoubtedly due to the fact that the brass is composed of one or more alloys or compounds.

DISCUSSION.

Mr. J. W. Richards: I wish, Mr. Chairman, that the ladies had been here to discuss this practical application of electrochemistry to the cleaning of silverware. I think Mr. Salom will recognize it as an application of cathodic reduction.

Mr. Salom: Yes.

A paper read at the Eighteenth General Meeting of the American Electrochemical Society in Chicago, Ill., October 15, 1910, President Wm. H. Walker in the Chair.

THE CORROSION OF METALLIC FOOD CONTAINERS—CAUSES AND PREVENTION.

By Dr. Edward Gudeman.

All of you know that if you have a product for analysis, that you will be satisfied to call it a C. P. product, if the amount of total impurities are 0.001 percent or less. Atomic weights generally do not go beyond the second decimal place and most chemists in figuring analytical results, use only the first decimal figure. In Food Chemistry a quantity of 0.001 percent is often considered a tremendous quantity, especially if it is a metallic impurity or an antiseptic or coloring ingredient, and I cite some cases to give you an idea how far some food chemists and food officials carry this "foolish accuracy," not to use a stronger term. Within the last few weeks there was submitted to me from outside of this State, some carbonated water, condemned as unwholesome and poisonous, due to its lead contents, and the distributers were given five days to take same out of the market. Analysis showed the amount of lead to be 0.00003 to 0.00005 percent. Another similar product was found to be free of lead as it was put into the container, but contained about 0.0003 percent lead after three days. The lead in this case came from the metallic button used to seal this special kind of bottle. In another case the trace of lead was found to be due to solvent action on the pipes used in the apparatus and the manufacturer was given ten days to take out the whole machinery and replace it with such machinery as would give a lead free product.

The stronger the corrosion of the metal, the quicker the solvent action. In the case where the metallic stopper was the cause of the lead entering the beverage it was found that the button used to hold the rubber cap, averaged in new buttons about 18 percent of lead. The old corroded button was found to contain about 8 percent of lead. The total amount of lead and tin that actually went into solution could not be exactly determined, as such

buttons vary in weight, but it was strongly indicated that approximately twice as much lead went into solution as of the tin. It was also found that the solvent action of carbonated waters on lead alloys was about the same as on the lead itself.

As another case showing to what foolish extremes of accuracy some food chemists will go, I cite the following: In one of our neighboring States the distributers of a food product, were given 10 days notice to clear the market of food product, said to contain a *quantity* of sulphur dioxide or its compounds. On request I investigated this matter and the chemist who made the analysis stated as follows: 200 grams of the product were taken for analysis, using the official methods, the distillation was continued until the distillate amounted to 2,500 c.c. To obtain complete oxidation, with bromine, this was concentrated down to 50 c.c., placed into a test tube and the sulphates precipitated with barium chloride. As no visible precipitate appeared, the solution was allowed to stand about 18 hours, the clear liquid carefully decanted and the bottom of the test tube examined with a magnifying glass, showing a thin film. The film was considered as barium sulphate due to the sulphurous oxide in the original product, and the product was condemned and the distributers and manufacturers given a short time to dispose of the stocks on hand. Duplicating the work quantitively it was found that the film would approximate 0.000001 per cent of the amount taken for analysis. Under the official standard for sulphurous oxide, pertaining to imported beverages, a maximum of 50 mmgs. free sulphurous oxide per kilo is permissible. Parties have been cited into the courts to defend the presence of a faint trace of nitrogen oxide in starch. The testimony showing that the amount present was less than found in the atmosphere under normal conditions and the defendants were discharged. Within the last month Federal Inspection Decision No. 126, places the maximum amount of tin allowed in food products at 300 mmg. per kilo, being 0.03 percent. Tin has been one of the substances most extensively used to protect iron from corrosion and until the issuing of the last Federal Inspection Decision was not legislated against, in fact standards were accepted for the amount of tin required on tin plate to make it acceptable to be used for the manufacture of food containers.

Tin, copper, lead, silver, and iron are very soluble metals, (especially when traces are taken into consideration) in the liquids found in canned food products and in the peculiar liquids produced in the decomposition of foods. It is immaterial how the food itself is protected, it will undergo some decomposition, not necessarily putrefaction, nor producing an unwholesome product. This decomposition is often a very slow one, not noticeable until months or years have passed since the product was put into the hermetically sealed container. Among the two most commonly found products of decomposition are sulphuretted hydrogen and carbonic acid. Carbonic acid is one of the strongest corroding acids known to me, especially when acting under pressure on metals in the presence of water. Some 18 years ago I was interested in the process of directly corroding lead with carbonic acid. Treating finely divided lead with carbonic acid under pressure would change the lead into carbonate in a very short time, the process being now in use for the manufacture of carbonate of lead, white lead, direct from the metal. The finely divided lead or lead sheets are subjected to water or steam under a pressure of carbonic acid. Carbonated beverages are always under carbonic acid pressure varying from 5 to 125 pounds per square inch, and the decomposition of food products giving rise to carbonic acid, produces a pressure and thereby solvent action is increased. This no doubt explains why food products placed in vacuum containers are less liable to deterioration.

Tin is a good protecting medium for iron under two conditions, you must obtain a perfect coating and you must obtain a perfect contact between the tin and the iron. I have never seen a piece of tin plate where both of these conditions were met with, and very few where either of these two conditions were found.

There are four main reactions that take place with food products, due to the character of the foods themselves or to their decomposition, under normal conditions of ageing. There is either oxidation or reduction, or both, and the action of acids or alkalies, or both. A perfect container would be one that would withstand all of these reactions. One cannot tell with certainty which reactions will take place, nor how they will take place, nor when. Iron is porous and in tin plating the pores are not filled or coated. Tin also is porous, and this porosity must be

taken into consideration. A perfect contact between the tin and the iron is of the greatest importance, using sufficient tin to coat all the superficial area of the iron. With such a tin plate, the corroding action on the tin need only be considered. After a large series of trials this object was attained, but the process is not commercially successful, as the cost of the container is a vital consideration, being about twice the value of the present tin can with its contents. Iron and steel can be impregnated so as to have the resisting properties of gold. Steel springs, knives, surgical instruments, etc., look like gold and have the insolubility of gold, with all the characteristic properties of tempered steel. The process is simple. I made an amalgam of gold and impregnated the iron article with such liquid amalgam, then by heat vaporized the mercury and obtained an iron gold article that withstood the corroding action of acids, exactly like gold. The amount of gold required was very small, about two ounces of gold to a ton of iron being sufficient, figuring this from the small experimental samples made. The serious objection to this process was that the amalgam of gold had to be liquid, and it was necessary to vaporize about 99½ pounds mercury for every half pound of gold used, an amalgam of over half percent not working satisfactorily. Experimentally the process is a success, but commercially the cost of operation is such that the cost of such a plate will be from 12 to 15 times the cost of tin plate, making the cost of the gold iron container exceed, often, the cost of the present container with contents.

Other liquid alloys were tried and some very peculiar results obtained. Copper impregnated with sodium amalgam was found to resist the action of acids and water to a greater extent than the metals themselves. I have no explanation to offer why a copper-sodium plate should resist acid more than the copper itself. The resistance of such a plate to water, being greater than the resistance of sodium itself, can be explained on the theory of the dilution of the sodium with the copper, thereby protecting the sodium from coming into contact with the water.

Very peculiar results were obtained when impregnating copper with antimony amalgam. It was found that such antimony-impregnated copper greatly resisted the action of dilute nitric acid, the amount of copper that went into the solution from the sur-

face contact being not over 10 percent of the amount that went into solution from the edges. The acid penetrated from the edges towards the center, and the rapidity of the solvent action of the acid from the edges towards the center was visibly noticeable. Strength of acid, temperature and time are factors that materially influence this action. Protecting the edges by dipping into paraffin, showed conclusively that the corroding action of nitric acid on copper was greater than on the same amount of copper impregnated with antimony.

Very extensively used for food containers are the so-called enameled cans. They are not real enameled cans, but simply metal plates on which an enamel was baked. Real enamel should become part of the whole and not simply a superficial protecting coating, that can be separated by mechanical means. Experiments were made to impregnate enamels in iron plates, but the high pressure required makes the process too expensive, to be commercially developed now. The enamel was forced into the iron plate at a pressure of about 50,000 pounds per square inch. The superficial excess coating of enamel was scraped off the plate, and the impregnated plate subjected to a heat sufficient to melt the enamel. Enamel impregnated iron plates withstood the action of acids and alkali fully as well as glass. There were many difficulties found in using enamels and experiments were then made to impregnate iron plates with glass. The results were most satisfactory, but until the process and products are fully protected by patents no details can be given.

The best results were obtained when using a very fusible lead glass. Such impregnated glass iron plates were found to resist the corroding action of food juices fully as well as the glass itself. The amount of lead that will go into solution has not yet been determined. Whether such a container will meet the requirements of food officials and food chemists, who condemn food products containing 0.00003 percent of lead and who consider about 0.000001 percent of sulphur dioxide as unwholesome, remains to be seen.

Chicago, Ill.

DISCUSSION.

Mr. J. W. Richards: I think some of the fluo-silicates may be found almost equally as fusible as lead glass, without containing lead. There is a large field for studying those fusible silicates, and I think a close study of them would be warranted.

Mr. Gudeman: That would be very nice, only under our food laws we get into difficulty if we have any fluorides present, even a quantity less than three hundred-thousandths of one percent would be objectionable to some of the food officials.

The Chairman: Is it not true that the pendulum has swung to the very extreme in regard to the metallic containers of food? Are we not perhaps going back to something more sensible and sane?

Mr. Gudeman: I cannot agree with your first remark, Mr. Chairman, because I believe it was only on the first of October that the last Federal Inspection Decision, No. 126, was issued, which put a limit even on tin, so we have not yet reached the extreme swing of the pendulum.

The Chairman: We are getting there very fast. We must be, because "sand always runs out in the end."

A paper read at the Eighteenth General Meeting of the American Electrochemical Society in Chicago, Ill., October 15, 1910; President Wm. H. Walker in the Chair.

ON THE RELATIVE BASICITY OF THE METALS AS SHOWN BY THEIR POWER TO REPLACE ONE ANOTHER IN CHEMICAL COMPOUNDS.

By Louis Kahlenberg.

Among the various types of chemical changes known at the present time the replacement of one metal by another is one of the most interesting. Changes of this character have been known for a long time. So Basil Valentine remarks that gold is precipitated from solutions by mercury, and iron precipitates copper from a solution of copper sulphate. Porta, an Italian investigator, described silver trees in 1567. In the middle of the seventeenth century Sala and Van Helmont insisted that the precipitated metal is not *produced* by the precipitant, but is simply thrown out of solution. Sylvius de le Boe knew of metallic precipitations and explained the phenomena correctly. Boyle showed that copper, which precipitates silver, is in turn thrown out by zinc or iron; he also observed that mercury precipitates silver as well as gold. In the eighteenth century, attempts were made to arrange the metals in a series in the order in which they precipitate each other from solutions. In 1782 Bergmann published an interesting paper on this subject. In the latter part of the nineteenth century, the idea gained ground that the replacement of one metal by another could only take place in electrolytes. Work in this laboratory showed, however, that this idea is erroneous, and that most of the typical chemical reactions will take place quite as readily in insulators as in electrolytes.[1]

These experiments have recently been greatly extended by further work in this laboratory. It is the purpose of the present note to indicate briefly some of the important results of these investigations. The reader who desires a description of the

[1] Kahlenberg, Jour. Phys. Chem. **6**, 6 (1902); Kahlenberg and Schlundt, *ibid.* **6**, 427 (1902); Kahlenberg, Zeit. Phys. Chem. **46**, 63 (1903); Mathews, Jour. Phys. Chem. **9**, 641 (1905); Sammis, *ibid.* **10**, 593 (1906).

experimental details of the method employed will find the same given in a paper by Charles Baldwin Gates, which will soon appear in the Journal of Physical Chemistry. Mr. Gates performed a very large number of experiments on the replacement of the metals by one another in non-aqueous non-conducting media.

Copper oleate will dissolve in kerosene, and the solution formed is an insulator. From such solutions zinc, cadmium, and lead will precipitate copper, while iron, cobalt, nickel, magnesium, bismuth, antimony, tin, and sodium do not affect the solution at all, even on heating for three hours to 100° C. None of the metals mentioned will precipitate copper from a solution of copper oleate in carbon disulphide (which solution is an insulator), even on heating under pressure to about 100°.

In acetone solutions of copper oleate, iron, bismuth, antimony, aluminum, zinc, copper, nickel, tin, cadmium, and magnesium were unaffected even after boiling for hours. In carbon tetrachloride solution of copper oleate, zinc and lead produced a granular precipitate of copper, but the other metals remained unchanged. When copper oleate was dissolved in amyl nitrate the metal was replaced by cadmium and lead. Bismuth was slightly tarnished, but the other metals above named were unchanged.

In toluene solutions, ferrous oleate or cadmium oleate may be boiled for hours with either magnesium, manganese, iron, nickel, cobalt, zinc, cadmium, tin, silver, aluminum, copper, antimony, bismuth, or lead without affecting any of the metals, except that lead is tarnished in the cadmium oleate solution.

From copper palmitate dissolved in toluene, none of the metals mentioned will throw out copper, except lead which shows a dark coating, and bismuth which is somewhat tarnished.

It is of special interest to note that while lead deposits copper at once from a solution of copper palmitate in pyridine, no change occurs when lead is introduced into a solution of copper abietate in pyridine even on prolonged boiling.

From pure, molten copper oleate or copper palmitate lead deposits copper, but not from molten copper abietate, even after long standing.

When heated to 100° in a solution of copper oleate in aniline, zinc and cadmium are slightly coated with copper, lead receives a bright red coating, but all of the other metals listed above are unchanged. In the corresponding solution in pyridine as solvent, both lead and cadmium precipitate copper and the other metals remain unaffected. In the same solution using toluene as solvent, lead precipitates copper on standing, or at once on heating. All of the other metals mentioned are unchanged, even after seven hours at 100°. Even when molten, sodium does not throw copper out of this solution.

When the oleate of manganese, chromium, nickel, cobalt, iron, or cadmium is dissolved in toluene and the solution boiled with all the above mentioned metals, only the lead is affected, being covered with a dark deposit.

From the results here detailed it is evident that in non-aqueous solutions the order of the metals when arranged in a series according to their replacing power or basicity is not the same as in aqueous solutions, though in the latter too the relative positions of the metals are by no means the same in all cases.[2] In the non-aqueous solutions here studied, the most striking characteristic is the strong basic property exhibited by lead, which is able to replace copper even in cases where sodium, magnesium, and zinc fail to do so. In the electrochemical series of the metals in aqueous solutions the order commonly given is about as follows: Alkali metals, alkaline earth metals, magnesium, aluminum, manganese, zinc, cadmium, iron, cobalt, nickel, lead, bismuth, antimony, tin, copper, mercury, silver, palladium, platinum, gold. On the other hand, in the non-aqueous solutions studied in this laboratory thus far, the replacements that have been secured would arrange the metals that have been tested about as follows: Lead, cadmium, zinc, cobalt, bismuth, magnesium, tin, mercury, iron, aluminum, antimony, nickel, silver. In all, experiments in about 69 different solvents have been performed in this laboratory. Some of the results obtained have already appeared in the article by Sammis above mentioned, but a much larger number will be presented in the article by Gates, whose experiments show that copper may be replaced from non-aqueous, non-conducting solutions not only by lead but, in certain cases, also by zinc, cadmium,

[2] See Kahlenberg, Trans. Amer. Electrochem. Soc. 6, 53 (1904).

tin, bismuth, antimony, mercury, silver, iron, nickel, cobalt, aluminum, magnesium, sodium, potassium and calcium.

It has been firmly established then that *the power of one metal to replace another is exhibited in non-electrolytes or insulators as well as in electrolytes, and is consequently not at all dependent upon electrolytic conduction.* However, in all cases it has been found that *whether replacement will occur or not depends not only upon the specific metals under consideration, but also upon the nature of the solvent employed and the nature of the acid radical with which the one metal is combined. Neither the specific inductive capacity of the solvent nor its co-efficient of association appear to have anything to do in determining whether the action in question will occur or not.* Thus it is evident that the power of one metal to replace another in aqueous, conducting solutions, is also exhibited in non-aqueous and insulating liquids, and we realize once more the truth of the old saying: "Das Wasser ist kein besonderer Saft."

In the course of these investigations some further interesting observations were made. Thus pure lead will precipitate copper from copper oleate solutions in toluene, and pure sodium will not do so, as already mentioned. Alloys of lead with sodium may be formed which also have no effect on the solutions in question. So an alloy of 20 percent sodium to 80 percent lead is but slightly tarnished in a copper oleate solution in toluene. Again an alloy of five percent tin and 95 percent lead no longer precipitates copper from this last mentioned solution, neither will an alloy of one percent cadmium and 99 percent lead. A further interesting experiment which may be of fundamental consequence showed that from a 2.5 percent solution of copper oleate in pyridine lead does not precipitate copper at room temperatures, but the precipitation does occur when the solution contains 2.75 percent of copper oleate. This matter is receiving further attention at present. The entire question of the replacement of metals by one another will be further investigated in this laboratory.

Chemical Laboratory,
University of Wisconsin,
Madison, September, 1910.

DISCUSSION.

THE CHAIRMAN: We have to thank Mr. Kahlenberg for showing us one more evidence that we haven't learned all about electric conductivity yet, as demonstrated by how one metal can replace another.

A MEMBER: I should like to ask Professor Kahlenberg if that experiment he spoke of last with 2.75 percent would go on below the 2.50 percent limit?

DR. L. KAHLENBERG: Apparently it does go on somewhat further, but you don't get complete precipitation. It is possible that on long standing it might be secured. We haven't followed that matter out yet. It is a subject for further investigation, still I did want to mention it here.

DR. RICHARDS: Since in aqueous solutions the replacement is very nearly in line with the heat of formation of the different compounds, I would like to ask Dr. Kahlenberg if he has found any relation at all between the heat of formation of the compounds and the replacement power of the metal?

DR. L. KAHLENBERG: The fact is, we know very little or nothing about the heat of formation of these compounds yet. In fact, we have just begun at the University of Wisconsin to study the thermal chemistry of non-aqueous solutions. The first paper on that subject will be presented at Minneapolis next Christmas.

DR. RICHARDS: If these stronger metals, as we ordinarily call them, are thrown out in a metallic state from these solutions, may it not lead to methods by which we can use the weaker metals for producing the stronger ones?

DR. L. KAHLENBERG: Yes, I think there are quite a few possibilities along that line. We haven't taken up the technical side of this at all. We are simply investigating the problem on general principles to get at the scientific question involved. It is extremely interesting that magnesium, which acts so vigorously in aqueous solutions, will remain unchanged in some of these solutions for years. I have had metallic magnesium in copper-oleate solutions in toluene for thirteen years. It remained just as bright as ever it was, and sodium was also kept unchanged in the same solutions.

A paper read by Dr L. Kahlenberg, at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, Ill., October 15, 1910, President W. H. Walker in the Chair.

CRYSTALLIZATION THROUGH POROUS DIAPHRAGMS.

By J. H. Walton, Jr.

If a supersaturated solution or an undercooled liquid is divided by a membrane, and crystallization is caused to take place on one side of the membrane by the addition of a fragment of the solid phase, it will also take place on the other side, the crystallization being transmitted through the membrane.

This was found to hold true with the following supersaturated solutions:

Sodium sulphate Sodium acetate Sodium tetraborate Sodium thiosulphate Potassium alum Lead acetate	Using as membranes Gold beater's skin Collodion Parchment

With rubber membranes no transmission occurred with the above solutions.

It was found, however, that with certain undercooled, organic liquids, crystallization could be transmitted in a similar manner through rubber membranes.

The substances used with rubber were:

Thymol
Salol
Acetophenone
Phenol plus a small amount of benzol (to aid in undercooling)

In each case the rubber membrane was found to remain intact at the end of the experiment.

The fact that this transmission of crystallization occurs only in those cases in which the membrane can be wet by the liquid seemed to point to the following explanation: The pores of the membrane are filled with the solution, and the separation of crystals occurs in them exactly as it would in a capillary tube.

To further test this point, experiments were made to see whether or not mere proximity of crystals to the supersaturated solution would cause crystallization.

A very thin rubber membrane was prepared by tying a piece of sheet rubber over the end of a tube. By blowing into the tube the rubber could be expanded—so that it had a thickness of only .0003-.0004 in. Such a distended rubber membrane was used to divide aqueous supersaturated solutions of

Sodium acetate
Potassium alum
Lead acetate

one part of the solution then being inoculated as with the other membranes. In no case, however, did transmission of crystallization occur even through these very thin membranes.

We may conclude then, that the presence of the solid phase is essential for the separation of crystals from a supersaturated solution; moreover, that a very small crystal will cause this separation, for in these cases the crystal could not be larger in diameter than the pores of the membranes.

The foregoing experiments were carried out with solutions which were very much supersaturated. Would this phenomenon occur in cases in which the solution was but slightly supersaturated? Saturated solutions of various salts were prepared at 30°. Definite volumes were taken, the temperature raised a few degrees, weighed amounts of the respective salts dissolved in the various solutions, which were then cooled to 30° C. again. Supersaturated solutions were prepared in this way; with the amount of solid which would separate from the solution on inoculation at 30°, varying from 1.2 to 4 gms. per 100 c.c.

Sodium acetate and potassium alum solution were used with parchment and collodion membranes. With each of these salts it was found that there is a definite limit of supersaturation below which transmission of crystallization through membranes does not occur. This limit varies with the solute and also with membrane.

The existence of this lower limit points to the fact that the solution within the membrane has a lower concentration than

the solution which surrounds the membrane. According to this theory, with a strongly supersaturated solution, crystals would be transmitted through the membrane. With a solution whose degree of supersaturation was equal to (or less) than the difference between the concentration of the solution in the membrane and that surrounding the membrane, no transmission of crystallization could occur.

Such a lowering of the concentration of the solution within the membrane could be explained by the formation of a compound of membrane and solute. In the membrane we would have not only supersaturated solution, but also this compound (membrane + solute) in equilibrium with solution in the pores, and it is easy to conceive of a case in which the solution is supersaturated to such a slight extent that the amount taken up by the membrane leaves in the capillaries of the membrane a solution just saturated or even less than saturated. Such a solution in the membrane would, of course, not permit the transmission of crystals.

This method, by which this lower limit can be measured, makes possible the measuring of how much of a solution is combined with the membrane, and should have importance in the study of adsorption phenomena.

For further experimental details concerning this paper, the reader is referred to the Journal of Physical Chemistry.

Chemical Laboratory,
University of Wisconsin,
Madison, September, 1910.

A paper read by Dr. L. Kahlenberg, at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, Ill., October 15, 1910, President W. H. Walker in the Chair.

ON THE EFFECT OF WATER IN CAUSING CHEMICAL REACTIONS.

By David Klein.

The great influence of water in accelerating various kinds of chemical changes has been considered by certain chemists as residing in some peculiar property of water. "Water is a substance whose presence, in at least minute amounts, seems to be essential to the occurrence of most chemical reactions. Moreover, its method of action is probably unique, consisting either in a hydration or electrolytic dissociation of the reacting substances. It is therefore not inappropriate that it alone constitutes a type of catalytic agent." (Noyes and Sammet.) The present investigation was undertaken to determine whether water is unique and exceptional, or whether other liquids possess the ability to initiate chemical change in a no less marked degree.

The particular reaction that was studied was that between hydrogen sulphide and sulphur dioxide. Nearly a century ago, Cluzel demonstrated that these gases will not react when sufficiently free from water. But no experiments are on record wherein organic liquids were substituted for the water, excepting two mentioned by Baker. It would require too much time to set forth the details of the experiments—the preparation, drying and storing of the pure gases; the purification of the organic liquids; the method of mixing the gases, and the admitting of the organic substance. These will be published in the near future.

Twenty-five liquids were investigated, of which fifteen will initiate the chemical change, as well as water. They are ethyl, isobutyl and isoamyl alcohols, acetone, methyl ethyl ketone, acetonitrile, propionitrile, valeronitrile, benzyl cyanide, methyl benzoate, propyl acetate, isobutyl acetate, ether, benzaldehyde and carvone. The liquids unable to accelerate the reaction are carbon bisulphide, ethyl disulphide, benzol, amylene, chloroform, carbon

tetrachloride, ethyl chloride, acetyl chloride, benzoyl chloride and nitrobenzene.

Explanations of these phenomena are not wanting, however untenable they may be. Baker concludes his Wilde lecture for 1909 as follows:

"Mr. J. C. Thomson has recently done some experiments for me on the hydrogen sulphide and sulphur dioxide mixture. He finds that liquid alcohol and liquid sulphur dioxide (both having high specific inductive capacity) can bring about the decomposition in the mixture; while carbon tetrachloride, whose specific inductive capacity is low, is inert. Also metallic aluminum and metallic mercury are apparently unable to effect the change."

This is evidently the Nernst-Thomsen rule in a slightly modified form. In the accompanying Table I there have been included the dielectric constants of the various liquids as given in the Landolt-Bornstein Tabellen (1905). A prediction from the specific inductive capacity would lead us far from the truth if it is maintained that any liquid possessing a high value will produce a reaction. For nitrobenzene, with a value of 36.45, and acetyl chloride (25.3) have no effect on the gaseous mixture; whereas either should act even better than the alcohols. On the other hand, ether, with a low value (4.3), can effect the reaction, while ethyl chloride (6.29) and ethyl disulphide (7.2) are inert.

That association in the liquid state cannot be a determining factor is clearly seen from the last column. Most of these values are taken from the works of Ramsay and Shields. Liquids, such as ether and benzaldehyde, which are unassociated, and methyl ethyl ketone, which is slightly so, if at all, are capable of affecting the mixture. Moreover, Baker found that liquid sulphur dioxide, also an unassociated liquid, will induce the change.

Armstrong views the matter as follows:

"Regarding the problem from the standpoint of Faraday's electrolytic studies, and in view of the well-known observations of De la Rive, Brereton Baker, Cowper and Dixon, I assume, however, that no two molecules can interact directly; that in all cases of chemical interchange (including electrolysis) the necessary *slope of potential* can only be provided by the inclusion of the interacting substances in a triple or tripartite conducting system."

Clearly this theory is untenable in the light of our knowledge of reactions in non-aqueous media. The reactions studied in this investigation cannot be viewed in the light of the theory of electrolytic dissociation, which Armstrong himself regards as untenable, or in the light of any theory involving electrical conduction.

Baker has revised his theory of these phenomena to accord with the very latest theory, that of the electrons, by insisting that free electrons must also form part of the reacting system.

TABLE I.

	Action	Dielectric Constant.	Association Factor.
Water	Immediate	80.0	3.60
Ethyl alcohol	Immediate	25.8	2.74
Isobutyl alcohol	Immediate	20.0	1.95
Isoamyl alcohol	Immediate	16.0	1.97
Acetone	Immediate	25.0	1.26
Methyl ethyl ketone	Less than 2 minutes	17.8	1.15
Acetonitrile	After 15 minutes	36.4	1.60
Propionitrile	After 7 minutes	26.5	1.77
Valeronitrile	After 15 minutes	17.4	
Benzyl cyanide	After 2 minutes	14.9	
Methyl benzoate	After 25 minutes	6.58	
Propyl acetate	Immediate	5.73	
Isobutyl acetate	After 6 minutes	5.26	
Ether	Less than 2 minutes	4.3	1.04
Benzaldehyde	Immediate	17.7	0.97
Carvone	Immediate		
Carbon bisulphide	None	2.64	1.07
Ethyl disulphide	None	7.2	
Benzol	None	2.28	1.01
Amylene	None	2.20	0.96
Chloroform	None	5.14	0.94
Nitrobenzene	None	36.45	0.93
Acetyl chloride	None	25.30	1.06
Benzoyl chloride	None		
Ethyl chloride	None	6.29	
Carbon tetrachloride	None	2.25	1.01

It has therefore seemed that a more satisfactory theory is that of intermediate compounds, whereby the catalyzer enters into a loose chemical combination with one or both of the reacting substances. Many examples of the action of hydrogen sulphide or sulphur dioxide upon the organic liquids employed in this investigation are recorded in Beilstein. The contention is not made that these compounds are intermediary in the reactions reported in this paper. They are inserted merely to emphasize

the possibility of chemical combination between the gases and the liquid. Nitriles unite with hydrogen sulphide to form thioamides $CH_3CN + H_2S = CH_3CSNH_2$. Aldehydes exchange their oxygen for sulphur $C_6H_5OH + H_2S = C_6H_5CHS + H_2O$. Addition compounds may also form $RCHO + H_2S = RCH{<}^{OH.}_{SH.}$ Both aldehydes and ketones form loose compounds with sulphur dioxide. Carvone yields a well-defined crystalline product with hydrogen sulphide $2C_{10}H_{14}O.H_2S$. In the case of the alcohols, it is clearly the specific properties of the hydroxyl group that come into play. Whatever rôle is assigned to water would apply equally well to the alcohols.

For further details concerning the experimental work, the reader is referred to the Journal of Physical Chemistry.

Laboratory of Physical Chemistry,
University of Wisconsin,
Madison, September, 1910.

A paper presented by F. C. Frary at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, October 14, 1910, President W. H. Walker in the Chair.

EFFICIENCY IN THE ELECTROLYTIC PRODUCTION OF METALLIC CALCIUM.*

By Francis C. Frary, Henry R. Bicknell and Carl A. Tronson.

Most of those who have worked on the electrolytic production of calcium have been content to describe their methods and apparatus, with perhaps an analysis of a selected lump of their product, but say nothing of the current efficiency obtained. Muthmann,[1] in the discussion of a paper by Rathenau, states that by using an electrolyte consisting of two parts of calcium chloride to one part of the fluoride, and raising the iron cathode as the metal accumulated, he obtained a "good" yield. Goodwin,[2] electrolysing pure calcium chloride in a similar way, obtained a current efficiency of 21.5 percent to 41.9 percent. Woehler,[3] using an electrolyte containing 100 parts of the chloride to 17 parts of the fluoride, claims an efficiency of over 80 percent, but states that the electrolyte deteriorated in time, probably owing to the formation of the hydrated oxychloride, and that hydrogen (!) is then liberated at the cathode, and the yield decreases. He used a current of 40 amperes at 33 to 38 volts, but does not say how often or for how long a time this efficiency could be obtained. Tucker and Whitney[4] improved the apparatus of Goodwin, and claim an efficiency of 60 percent, using the pure chloride as electrolyte, but give no data to support the claim. As far as we are able to ascertain, no one else has published any results on the efficiency of the various processes which have been proposed.

During previous work in this laboratory,[5] efficiencies as high as

* The work described in this paper is a continuation of that published by Frary and Badger, (Trans. Am. Electrochem. Soc., 1909, **16**, 185) where a summary and discussion of previous work on the electrolytic production of calcium will be found.

[1] Z. Elektrochem., **10**, 508 (1904).

[2] J. Am. Chem. Soc., **27**, 1403 (1905).

[3] Z. Elektrochem., **11**, 612 (1905).

[4] J. Am. Chem. Soc., **28**, 84 (1906).

[5] Frary and Badger, loc. cit.

46 percent were obtained, but, unfortunately, the only runs in which the necessary data were taken were made under unfavorable conditions. As it was certain that better results could be obtained and had been obtained in some of the runs for which no data were at hand, these were not published at the time, and the work was continued by the present authors.

The apparatus used was the same as that described by Frary and Badger,[5] and consisted essentially of a large crucible of Acheson graphite having a water-cooled bottom and serving as anode, and a water-cooled iron cathode a little over an inch in diameter. The crucible was enclosed in a protective layer of refractory material, and especial pains were taken with the contact between it and the positive cable. The cathode could be raised or lowered at will by means of a screw mechanism.

From preliminary experiments, it was decided that the occasional feeding of the fresh electrolyte and irregular raising of the cathode were two important causes of low efficiency. Intermittent addition of electrolyte caused irregularities in the height of the melt and its temperature, especially the latter. Too great cooling of the electrolyte caused the deposition of the metal in a spongy form, in which state it was readily lost. Spongy portions were also formed when the stick of metal extended too far below the surface of the melt, the current density[6] being insufficient to melt the metal at the point of contact with the electrolyte, and thus produce a solid stick. This spongy metal was very likely to be dislodged and swept away by the vigorous convection currents which were always present; it also gave trouble by growing toward one side or other of the crucible, causing an increase of current at that point, with consequent increased growth of metal and a higher temperature, until finally the calcium on the edges would melt, and, being connected with the main stick only by thin pieces of metal, would be easily swept away by the electrolyte. When the end of the stick of metal was kept just below the surface of the electrolyte, the spongy metal at first formed melted almost at once, and its surface tension drew it into a compact globule which was almost immediately frozen by the cooling effect of the rest of the stick and the water-cooled cathode. Thus

[6] In most cases a rod of about 1 cm. diameter was obtained, so the cathode area was about 1 to 1½ sq. cm.

a solid stick was easily obtained. To get the best results, it was found necessary for one person to devote all his attention to the raising of the cathode and the addition of the electrolyte, making both operations practically continuous.

The chloride used was some of Merck's C. P. granulated, which had previously been used in dessicators. It was dried in an iron crucible over a four-post bunsen burner, and preserved in a stoppered bottle.

In starting up a run, the cold fused chloride remaining in the crucible from a previous run was heated until dry by directing the flame of a blast-lamp upon it. Then a small portion of it was fused by drawing an arc from the side of the crucible with the aid of a graphite rod. A small current was used until contact was made with the cathode, when more current was put on and the graphite rod removed. As soon as good contact was assured, the direct current was shut off, and an alternating e. m. f. of about 30 volts applied. The current usually rose rapidly to about 200 amperes, being regulated by raising or lowering the cathode, and the upper part of the crucible was soon filled with the molten chloride. A sufficient supply of electrolyte was added at this time to fill up the crucible, and when all was ready, the alternating current was thrown off and the direct current thrown on. Readings of the time, voltage and amperage were taken at once. The voltmeter and ammeter were read every five minutes during the run, and the average of these readings considered to be the average voltage and amperage for the run. The current varied very little during each run, as it was taken from the 110-volt lighting circuit through a constant resistance. There was no trouble with the so-called "anode effect," except when the electrolysis was started before a sufficient amount of the electrolyte had been melted down by the alternating current.[7]

The formation of the metal under the cathode was watched very carefully, great care being necessary to get a good start. We aimed to withdraw the cathode and metal as rapidly as it was possible to do so without striking an arc. It will be noticed in the table of results that practice in doing this increased the

[7] A sample of the electrolyte was taken at such a time, when the "anode effect" had been more than usually troublesome, and the percent of silica present determined. Only 0.056 percent was found, confirming the results obtained in the previous paper, and indicating that current density rather than impurities should be blamed for this "effect."

yield obtained. When the electrolysis is going on properly, and the stick of metal is at the right depth, the electrolyte seems to flow rather rapidly across the surface in a fixed direction, and is hottest at the cathode. The operator must be guided by the appearance of the electrolyte at the cathode. There should be a rosette-like spot with radial markings here; if the stick of metal is pulled out too fast, this spot becomes almost white hot, and if the metal is not at once lowered, an arc forms, and part of the metal is melted off and lost. If the stick is not raised fast enough, the spot becomes less noticeable, and spongy metal deposits below the surface, causing losses. When the electrolysis was well under way, new electrolyte was added in small portions, taking care to make these additions as continuous as possible, and in such a spot that the convection currents carried the cold chloride away from the metal. The following table shows the efficiency obtained:

TABLE I.

Run No.	Time Min.	Amperes	Volts	Weight Gm.	Efficiency Percent
1	60	74.45	18.3	30.8	55.3
2	60	73.9	21.4	25.	45.2
3	60	74.2	21.	43.5	78.4
4	38	73.2	26.	27.	77.8
5	32	73.1	24.4	26.5	90.7
6	30	71.5	25.5	24.	89.8
7	27	70.4	33.	21.5	90.5
8	30	69.66	28.	26.	100.
9	34	52.54	34.	21.6	97.
10	36	68.75	31.	31.	100.5

The sticks of metal were cleaned by hammering off the crust on the outside, and then placing them in absolute alcohol for 24 hours to remove the rest of the chloride. When taken out of the alcohol, the sticks were always clean, though covered by a thin coat of oxide. They were dried by burning off the alcohol, and weighed. The current was, of course, not absolutely constant, so there is a possible error of one or two percent in the efficiency as calculated, but the results are sufficiently accurate for practical purposes.

Since Ruff and Plato,[8] Muthmann,[9] and Woehler[10] have recommended the use of a mixture of the chloride and fluoride as the electrolyte, we decided to try it and see if it offered any advantages. The fluorspar was first partially purified by treatment with concentrated hydrochloric acid to remove iron. It was mixed with the chloride in the proportion of 16.5 parts to 100, as recommended by Ruff and Plato. A new crucible was made for use with this electrolyte, having the same size as the other, but a different arrangement of the water-cooling. The bottom of the crucible was turned out on the lathe so as to fit loosely over the hollow brass cooling cylinder of the Borchers[11] furnace for the electrolysis of fused salts. The crucible was then turned upside down, this space filled with a strong copper sulphate solution, and copper deposited until the cylinder would not enter the space. The copper was now turned out on the lathe to fit the cylinder, and the whole of the outside of the crucible and cylinder protected from the air by a coat of Portland cement and carborundum fire-sand, held in place, as before, by a tin form. The contact, being made through the water-cooling cylinder, was kept cool and did not burn away, as the other crucible did in the course of time. A more complete protection of the outside of the crucible was also possible.

With this crucible and the above-mentioned electrolyte a new series of runs was made. Considerable trouble was found in making smooth, solid sticks of metal with this electrolyte. The particular advantage of this mixture is supposed to be its low melting point (660°). This appears to us to be a disadvantage, as the bath must be worked at a temperature of nearly 750° in order to get a solid stick of metal, and the bath is so fluid at the working temperature that convection currents are more violent and more likely to sweep away the metal from the end of the stick, forming an arc. We had a great deal of trouble from this cause. Reduction of the current did not bring the desired result, as the efficiency decreased markedly (Run No. 6, Table II). The following results were obtained:

[8] Ber. **35**, 3612 (1902); **36**, 491 (1903); D. R. P. 153, 731 (Chem. Centr. 1904, ii, 802.)

[9] Z. Elektrochem., **10**, 508 (1904).

[10] Z. Elektrochem., **11**, 612 (1905).

[11] Borchers, "Die Elektrische Oefen," 1907 ed., pp. 35 and 36.

TABLE II.

Run No.	Time Min.	Amperes	Volts	Weight Gm.	Efficiency Percent
1	30	42.	. . .	15.	95.5
2	32.5	41.5	31.	15.	89.2
3	42	53.9	37.	27.	95.7
4	35	45.6	31.3	12.8	64.4
5	9	54.9	26.	5.	81.2
6	41	31.9	30.	5.	30.6
7	45	52.1	29.5	18.	61.6
8	45	53.5	30.7	26.	86.6
9	46	69.3	31.4	29.4	74.
10	40	52.7	34.	22.6	86.
11	35	53.5	30.8	20.	85.5

During the runs with this electrolyte, only the chloride was added, it being assumed that the fluoride would not be decomposed. However, at the close of these experiments, a sample from the top of the melt showed only 2.21 percent of insoluble matter, so, evidently, much of the fluoride had been lost. This loss was probably largely mechanical and due to the violent spattering of the electrolyte; it was noticed that a great deal more of the fine dust from the electrolyte collected on the crucible and its surroundings with this than with the simple chloride electrolyte.

We also took samples from the electrolyte in the lower part of the crucible, which had been kept frozen during the electrolysis by the cooling coil, and so, presumably, retained its original composition, and attempted to isolate the fluochloride of calcium described by Poulenc[12] and Defacqs,[13] but found none of it.

From our experience with both electrolytes we believe that the plain chloride is a little more satisfactory than the mixture of the chloride and fluoride in point of efficiency, and decidedly easier to manipulate. We have shown that satisfactorily high efficiencies can be obtained with it, and that efficiency is more largely a matter of careful regulation of conditions than anything else.

University of Minnesota,
September 9, 1910.

[12] Ann. Chim. Phys., [7], 2, 5 (1894).

[13] Ann. Chim. Phys., [8], 1, 337 (1904); Compt. rend., 137, 1251 (1903); J. Chem. Soc., 86, ii, 123 (1904).

DISCUSSION.

MR. CARL HERING: I would be interested in knowing if you have any figures on the commercial efficiency obtained at Bitterfeld.

MR. F. C. FRARY: No figures have been published with regard to the commercial efficiency at Bitterfeld. If you will look at the tables given here, you will find the voltage required in the cells as used. You notice it varies between about 18 and 34, according to conditions, especially temperature and the size of the stick of metal. So we could not possibly have an energy efficiency of much over 10 percent, but we must remember that the rest of the energy is not wasted, because it is used to keep the bath at the proper temperature. We have the same condition, perhaps, as in the preparation of aluminum, where the bath is heated by virtue of its resistance and no external heating is needed. The temperature is much more simply and easily controlled than if one had to heat the crucible externally.

MR. J. W. RICHARDS: I think it is possible that if the calcium metal comes in contact with graphite at a low red heat, that calcium carbide will be formed, because under those conditions I have myself formed calcium carbide from calcium and graphite at a low red heat, the temperature rising because of the heat of formation of the carbide.

MR. FRARY: We have done that also in the laboratory. We attempted to melt calcium in a graphite crucible. As quick as the calcium melted it combined with the graphite to form carbide, so there is no question about the formation of calcium carbide being possible at that temperature.

A paper presented at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, October 14, 1910, President W. H. Walker in the Chair.

THE ELECTROLYTIC PREPARATION OF CALCIUM

By Arden R. Johnson.

It is the main purpose of this paper to set forth the most essential results of considerable experimental work upon the electrolytic preparation of metallic calcium, carried out in the electrochemical laboratories of the University of Wisconsin during the school year 1905-1906. The work was written up and presented as a thesis toward the baccalaureate degree in engineering, but was never published in a scientific journal.

Several good papers have been published in the last three or four years on the preparation of calcium, some by members of this society. It is therefore my object to present only data and statements that will largely supplement or reinforce much that has already appeared in print in leading journals.

While the thesis as originally written up four years ago contains an historical review of experimental endeavors in this line, I shall forego the presentation of the same here for the reason that the work has already been well given by Mr. F. C. Frary.[1] But my observations and data obtained upon two or three typical styles of apparatus much used,—apparatus with typically inherent faults, and also an electrolyte with all the common capricious properties, will, I think be of some value to the many electrochemists who, of late, have become interested in the chemical and metallurgical properties of this element.

The main efforts to produce calcium seem to have been through the medium of a correctly designed apparatus for electrolyzing, and if we glance over the different designs we shall recognize just two different types: First, the apparatus of the Borchers type for utilizing an extremely high current density and consequently obtaining the calcium in a molten condition, in which

[1] These Transactions, 16, 185 (1909).

it rises to the surface and is skimmed off, and secondly, the Rathenau type, which requires that the calcium come out in a

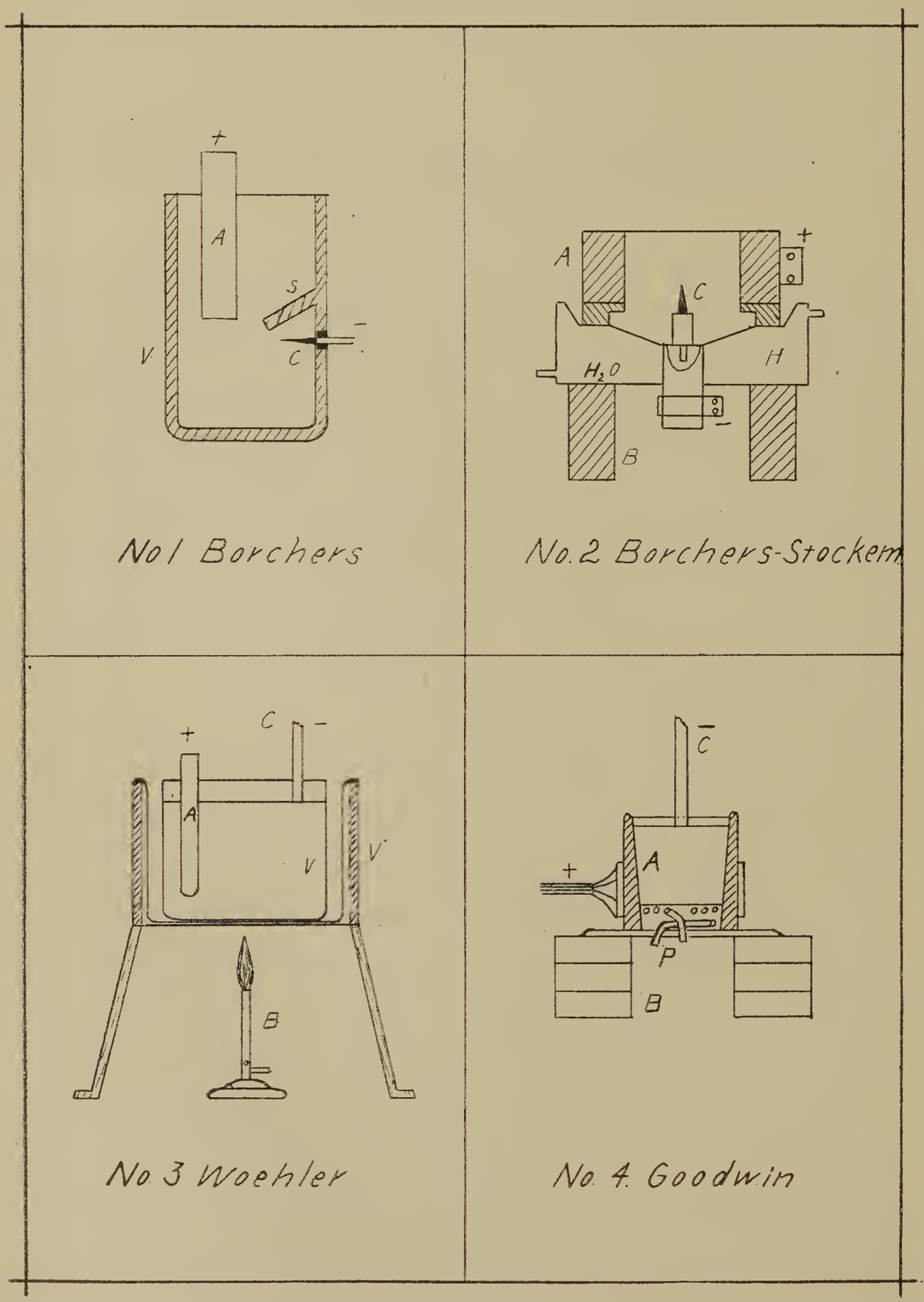


PLATE I.

compact form, that is, plated out at a moderately low current density.

PLATE I.

No. 1. Borcher's Apparatus.
V—Iron container for electrolyte.
A—Carbon anode.
C—Iron needle cathode insulated from container.
S—Shelf under which molten calcium may collect.

No. 2. Borcher's-Stockem Apparatus.
A—Circular graphite anode.
C—Iron needle cathode.
H—Water-cooled bottom insulated from anode.
B—Brick support.

No. 3. Woehler Apparatus.
A—Graphite anode.
C—Iron cathode.
V—Iron electrolyzing vessel.
V′—Sheet-iron jacket.
B—Bunsen burner for melting bath.

No. 4. Goodwin Apparatus.
A—Graphite, circular anode container.
C—Iron cathode (fastened to stationary upright screw).
P—Water pipes for keeping bottom of vessel cool.
B—Brick support.

EXPERIMENTS WITH APPARATUS NO. I.

In view of the successful results which have been attained by the above mentioned experimenters using the Rathenau type of apparatus, I decided also to begin the study of the electrolysis of $CaCl_2$ with an apparatus of this class. Accordingly the design shown in Plate II was followed, making use of such data concerning dimensions of anode and cathode as could be gleaned from the published description of Goodwin and Woehler's apparatus.

While a goodly number of trials with this apparatus were carried out, most of which were not over two to three hours duration, only three or four performed under different conditions will be described.

A run was made using pure $CaCl_2$ of the very best grade, made by Baker & Adamson. The cylindrical, graphite vessel was filled with $CaCl_2$ and then by the use of the auxiliary electrode an arc was struck with the inner surface of the anode container, and the $CaCl_2$ gradually melted down in the vicinity

of the arc until a small pool of fused $CaCl_2$ was formed. The auxiliary electrode was now inserted directly into the fused $CaCl_2$ and the current caused to flow through the bath directly. When sufficient electrolyte was melted the iron cathode R was

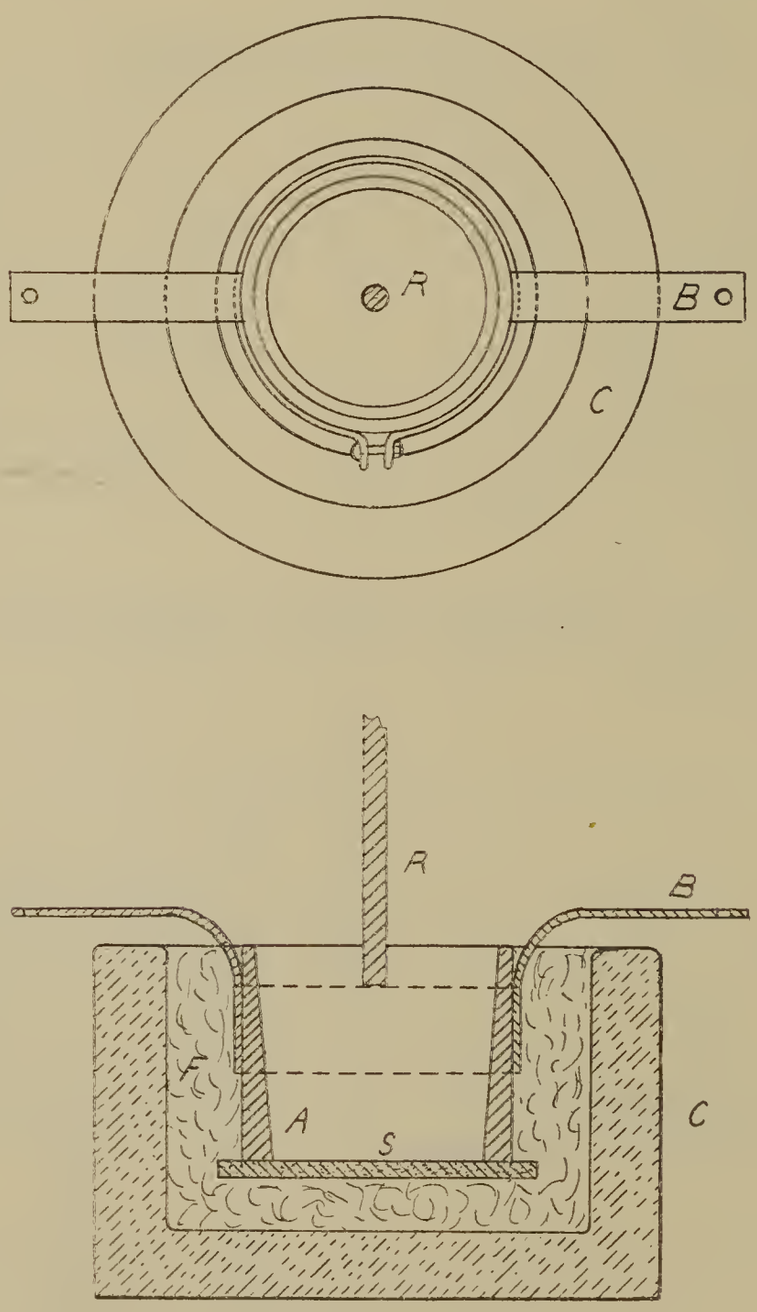


PLATE II.

Electrolyzing Apparatus No. 1.

A—Circular graphite anode.
B—Metallic conductor connecting with bands on anode vessel.
S—Soapstone bottom for anode.
C—Portland cement vessel.
F—Space filled with asbestos-cement.
R—Iron rod cathode (fastened to a stationary upright screw).

lowered into the molten mass by means of the screw (R′) and electrolysis begun. After a period of three or four minutes at most the odor of chlorine was noticed, and there was considerable cracking and snapping at the cathode and bursting forth of yellow flames. The current was gradually increased until finally the whole bath was in a state of fusion and 90 to 100 amperes were flowing. After waiting some minutes the iron cathode was cautiously raised from the bath, but nothing was observed until an arc was struck between the end of the rod and the surface of the bath. The rod was again lowered and electrolysis continued for 15 to 20 minutes, at the end of which time bright beads of metallic calcium were noticed to coalesce around the iron rod and finally break away and swim around in the bath under the influence of the convection currents. It was immediately recognized that a furnace of the Borchers type was at hand, so the current was gradually cut down as low as 40 to 50 amperes, (10 volts drop across cell) at which point a reguline deposit was noticed forming at the end of the rod. But it was now found impossible to keep all the bath fused next to the anode, and finally there was only a comparatively narrow channel of molten salt between anode and cathode. A glowing phenomenon, like a sheet of small arcs, was noticed at the anode. After the bath had been in operation under these conditions some time the iron rod was raised a trifle and electrolysis continued. The calcium "rod" which was forming was very irregular in cross-section, and continued in spite of all efforts to "neck down" until the "rod" suddenly melted, causing an arc and interrupting of electrolysis. Part of the calcium formed was skimmed out before the bath solidified and the remainder gotten afterwards by loosening the solid $CaCl_2$ from the walls of the anode vessel by immersion in H_2O and then breaking the solid chunk to pieces.

It was also noticed in this bath, as well as in all others, that the current had passed through the bath comparatively near the surface and hence the bath was melted to only a shallow depth, while at the bottom of the anode containing vessel the bath had remained solidified and almost pure white, though the upper portion through which the current had passed for a long time during electrolysis was very dark colored.

Woehler used a mixture of 100 parts of $CaCl_2$ and 17 parts of

CaF_2 by weight for his bath, thus getting an electrolyte which fused at a much lower temperature. Hence several trials were carried out in the apparatus described using such an electrolyte. The $CaCl_2$ was from the same bottle as that used in the previous trials, while the CaF_2 was ordinary powdered fluorspar.

The two salts were intimately mixed together and then fused down as previously described. After adjusting the current to 40 to 50 amperes it was noticed that a larger portion of the bath was kept in a fluid condition than when $CaCl_2$ only was used as electrolyte. Again the melt seemed to be more liquid. Calcium was noticed to form quite rapidly at the cathode but not in a good, compact form. It grew out from the end of the iron rod in a very irregular manner, tending to extend across the anode and short circuit the bath. Difficulty was experienced in getting a piece even an inch long on the iron cathode, an arc always being struck and melting off all the calcium.

While no attempt will be made to discuss here the chemical phenomena of the baths tried, it may be well to point out the mechanical defects of the apparatus as viewed from an engineering standpoint.

1. The parts of the apparatus (anode container and cathode) are wrongly proportioned to obtain proper cathode current density and still keep the electrolyte in a proper state of fusion.

2. The space intervening between anode and cathode is too small, allowing short circuits to occur.

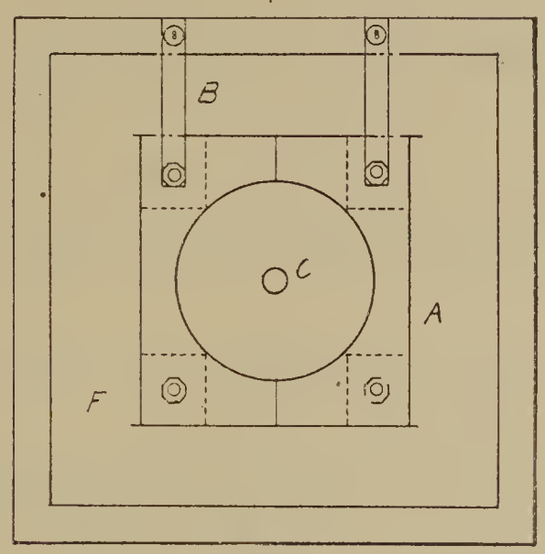
3. The upper portion of the graphite anode vessel exposed to the air rapidly disintegrates, allowing carbon to fall into the bath.

4. When the bath solidifies the graphite anode container is cracked to pieces.

5. The metallic bands around the anode vessel become badly corroded, causing poor contact.

EXPERIMENTS WITH APPARATUS NO. II.

In order to obviate some of the objections to the foregoing apparatus and at the same time have an apparatus practically the same capacity as Goodwin's, I designed that shown in Plate III.



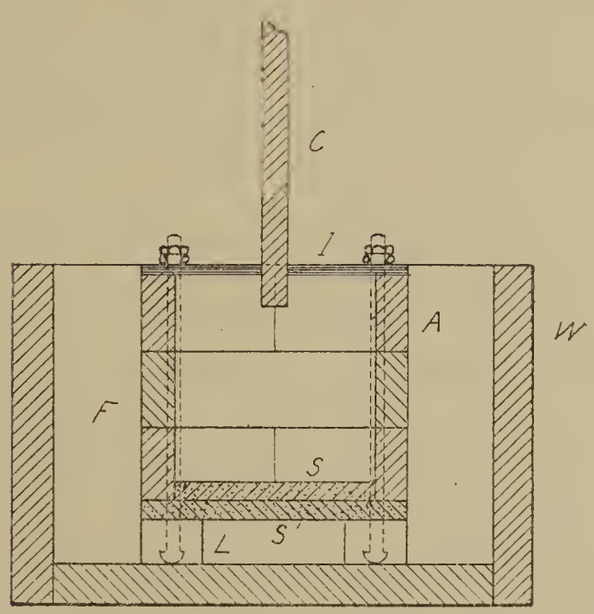


PLATE III.

Electrolyzing Apparatus No. 2.

A—Graphite anode built up of six sections, and held together by bolts in corners.
W—Wooden case.
F—Intermediate space packed with asbestos cement.
S—Loose soapstone bottom.
S'—Soapstone bottom bolted fast to anode.
L—Carbon legs.
C—Iron cathode (fastened to stationary upright screw).
B—Copper conductors leading to iron covering, I, which is held down on the top of anode by the corner bolts.

My chief aims in the design of this apparatus were as follows:

1. To have an anode vessel with the same internal dimensions as Goodwin's apparatus.

2. An anode container which would not be cracked to pieces when the bath solidified and could be subjected to heavy currents and hard usage.

3. Large enough space between anode and cathode so that iron rods of various cross-sections could be tried as cathodes.

4. An apparatus which would have as little radiating surface as possible.

5. To have the exposed portions of the graphite container protected from the atmosphere.

In almost all the trials with this apparatus the $CaCl_2$ and CaF_2 were in the proportions of 100 to 17 respectively. Some of the experiments were carried out with the pure so-called anhydrous $CaCl_2$ which has hitherto been described, while others were performed using crystalline $CaCl_2$ which was first dehydrated. I shall first describe a run for calcium using the pure "anhydrous" $CaCl_2$.

A granulated carbon resistance furnace was first constructed and a weighed amount of $CaCl_2$ placed in a Battersea clay crucible which sat in the carbon resistor. As the $CaCl_2$ warmed up some steam came off and then a very little HCl. The whole mass then came to a state of quiet fusion at a very light cherry-red color. Approximately the requisite amount of CaF_2 was now slowly added and its action in the bath observed. The CaF_2 seemed to gradually and easily dissolve in the bath. At the same time the bath as a whole grew more and more fluid and limpid. When all of the CaF_2 had been added the bath seemed to have a cloudy appearance, some portions being rather transparent, while light yellow clouds floated about in other portions. After agitation and maintenance of bath in fused condition for some time it became fairly homogeneous and opaque in appearance.

From the Battersea crucible the fused mass was poured into the electrolyzing apparatus. An alternating current was now passed through the bath using a carbon rod an inch in diameter as the second electrode. A sufficient current to keep the electrolyte in a well fused condition was found to be about 200 amperes. At the surface of contact of the large electrode with electrolyte all was quiet excepting perhaps now and then a faint glow. The small electrode, however, was completely enshrouded with first a glowing sheet of flames and outside of this a circle of yellow

flames bursting from the surface of the bath. In the space intervening, only now and then appeared a small yellow flame.

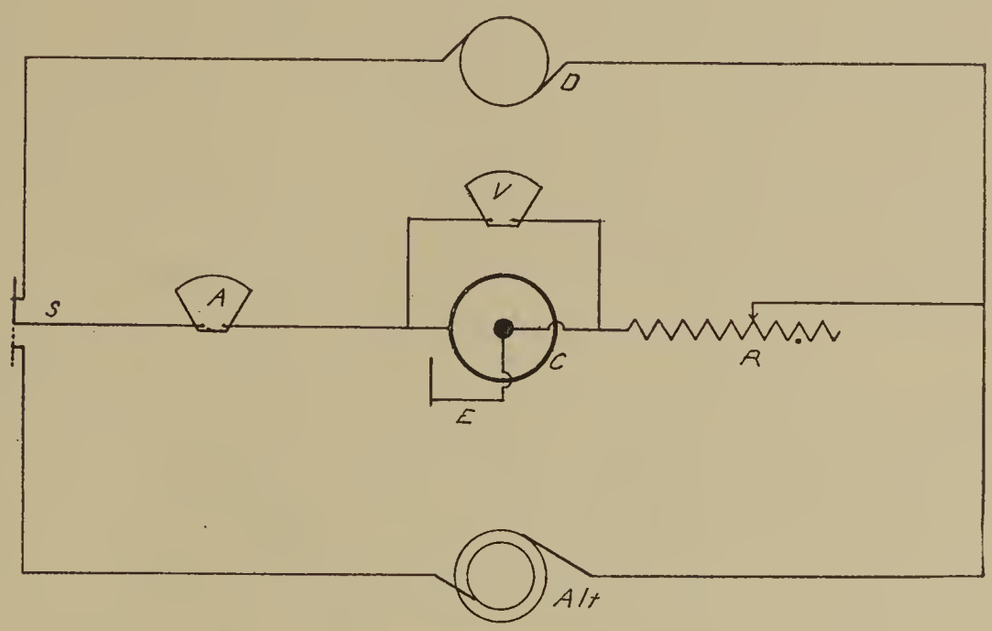


PLATE IV.

Showing Connections for Apparatus Nos. 2 and 3.

C—Electrolyzing vessel.
E—Auxiliary electrode.
V—Voltmeter.
A—Ammeter.
S—Switch.
R—Rheostat.
D—Direct current dynamo.
Alt.—Alternator.

The alternating current was now switched off and the direct current switched on after first replacing the small electrode with an iron one 1 centimeter (3/8 inch) in diameter. Chlorine was immediately detected coming off, and after some time calcium was noticed at the cathode, but it was soon in a molten condition and had to be skimmed from the bath. The current was gradually cut down to 75 or 80 amperes before calcium would adhere to the end of the rod in a reguline condition. With this current, however, only about 1/4 to 1/3 of the bath was fused. A sort of irregular mass of metallic calcium plus adhering $CaCl_2$ was built out from the end of the rod, after an hour's run.

The presence of water in the $CaCl_2$ has an important influence upon the results attained, and in view of this fact several runs

were tried using $CaCl_2$ which had been subjected to dehydration as follows: $Ca.Cl_2$ loaded down with water of crystallization was placed in the Battersea crucible of the electric resistance furnace afore described, and gradually "boiled down." When the mass had reached a pasty condition, a considerable volume of HCl came off, and then it soon began to melt down into a cherry-red, pasty fluid. Small bubbles of gas were noticed rising to the surface, exploding with a loud report and bursting in a yellowish flame sometimes tinged with a bluish color.

All of the electrolyte was next poured into the electrolyzing apparatus and subjected to a high temperature by passing an alternating current of about 200 amperes. A profusion of yellow flames was noticed bursting forth from around the small electrode and the whole surface of the electrolyte became covered with large transparent bubbles, up to 2.5 cm. (1 inch) in radius, of gas (hydrogen) which burst into highly colored flames with a loud report. If the heating be continued these transparent bubbles almost entirely disappear after a time, but no matter how long we continue to heat the electrolyte (or electrolyze) we never get rid of the small yellow flames around the smaller electrode (cathode, if electrolyzing).

Now there are two conditions under which we may electrolyze the above mentioned electrolyte: (a) Electrolyze after all of the gas bubbles (excepting those giving yellow flames) disappear; or (b) electrolyze before the formation of bubbles ceases.

In the first case chlorine is noticed coming off immediately after switching on the direct current. Metallic calcium also appears at the cathode and comes out regularly, if proper conditions of temperature and current are maintained.

On the other hand, if we attempt to electrolyze before the $CaCl_2$ is as thoroughly "dehydrated" as possible, that is, before the cessation of gas formation, we get entirely different results. If the bath has been heated little previously, we get almost no chlorine given off at the anode, while at the cathode nothing is deposited if the temperature and cathode current density are high, and if within proper limits, a black, crispy mass resembling charcoal in appearance, and having seemingly good electrical conductivity, is formed. By long continued electrolysis one may

succeed in finally getting a poor reguline deposit, but the bath acts very capriciously at all times.

In a preceding paragraph was set forth the chief aims in the design of apparatus No. 2, with which the above experiments were performed. These experiments have shown the apparatus to fulfill most of the requirements, but before proceeding with the chief objections to this general type of apparatus (Rathenau principle) for use either as a commercial apparatus or for carrying on research work, it is first desirable to give some facts concerning the physical nature of the deposit of calcium and the manner in which it forms in reguline condition.

Of course, it will be assumed that the electrolyte is in good working condition chemically and otherwise, all conditions being such as to contribute to the best formation of metallic calcium. My experiments have shown that whether the metal comes out with a coarse crystalline structure (as it usually does), or in a compact, dense form, the deposit cannot form to any great thickness before becoming nodular on the surface, or even growing out in arborescent forms.

From analogy with the nature of deposits from aqueous solution (and also because of the particular design of apparatus used), the above results might be anticipated. In the refining of metals from aqueous solutions by electrolysis it has been found practically impossible to obtain a smooth deposit deeper than 4 cm. (1.5 inch), and in most cases the deposit becomes very nodular and uneven by the time the deposit is 1.25 cm. (½ inch) thick.

There is no reason to believe that a reguline deposit from $CaCl_2$, or any other fused electrolyte should come out in a smooth compact form for a practically indefinite thickness than there is in an aqueous solution. A glance at photograph (V) of a calcium deposit which has been sawed through, will show that these formations have a core of fairly solid metallic calcium. This core is particularly solid near the base of the iron rod, but as we leave the center of this core and approach the outside of the formation we find the metal becoming more and more irregular and mixed mechanically with more or less $CaCl_2$. Still farther from the center of the core the metallic calcium and $CaCl_2$ are hopelessly mixed together. (This fact has an important bearing

upon the values obtained for current efficiency, as will be shown later.) To be sure, an irregular cathode deposit of considerable length can be formed but there is a greater waste of calcium and $CaCl_2$ and hence lower and lower efficiency as the "rod" grows longer, on account of the increased mixing of the electrolyte with the metallic calcium formed. It must be borne in mind that a piece of this deposit, consisting of metallic calcium and $CaCl_2$ so intimately mixed mechanically as to appear almost homogeneous, can still be a very good conductor of the electric current and hence may act as a cathode surface for a further deposit

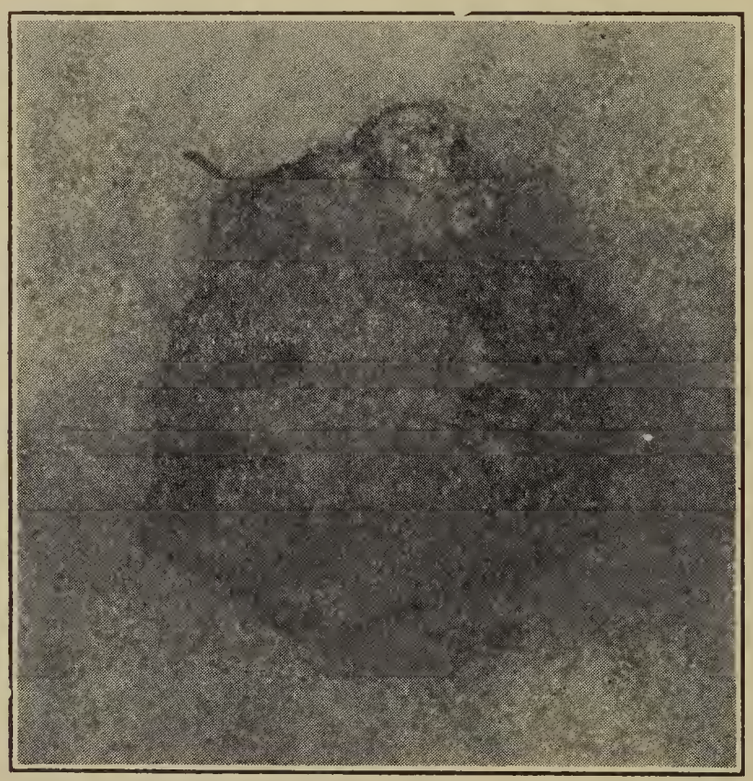


PLATE V.

of metallic calcium, or a mixture as described, so that a stick of "metallic calcium" such as this is easily obtained.

Again, as intimated above, the particular design of electrolyzing apparatus used is such as to cause the formation of a more or less irregular calcium deposit. When we pass an electric current through this apparatus the current will seek that path which offers the least resistance, and of course we find the lines of current flow as near the surface of the electrolyte as possible. Indeed, as a consequence the bath remains comparatively shallow in spite of a considerable increase of current. We cannot put

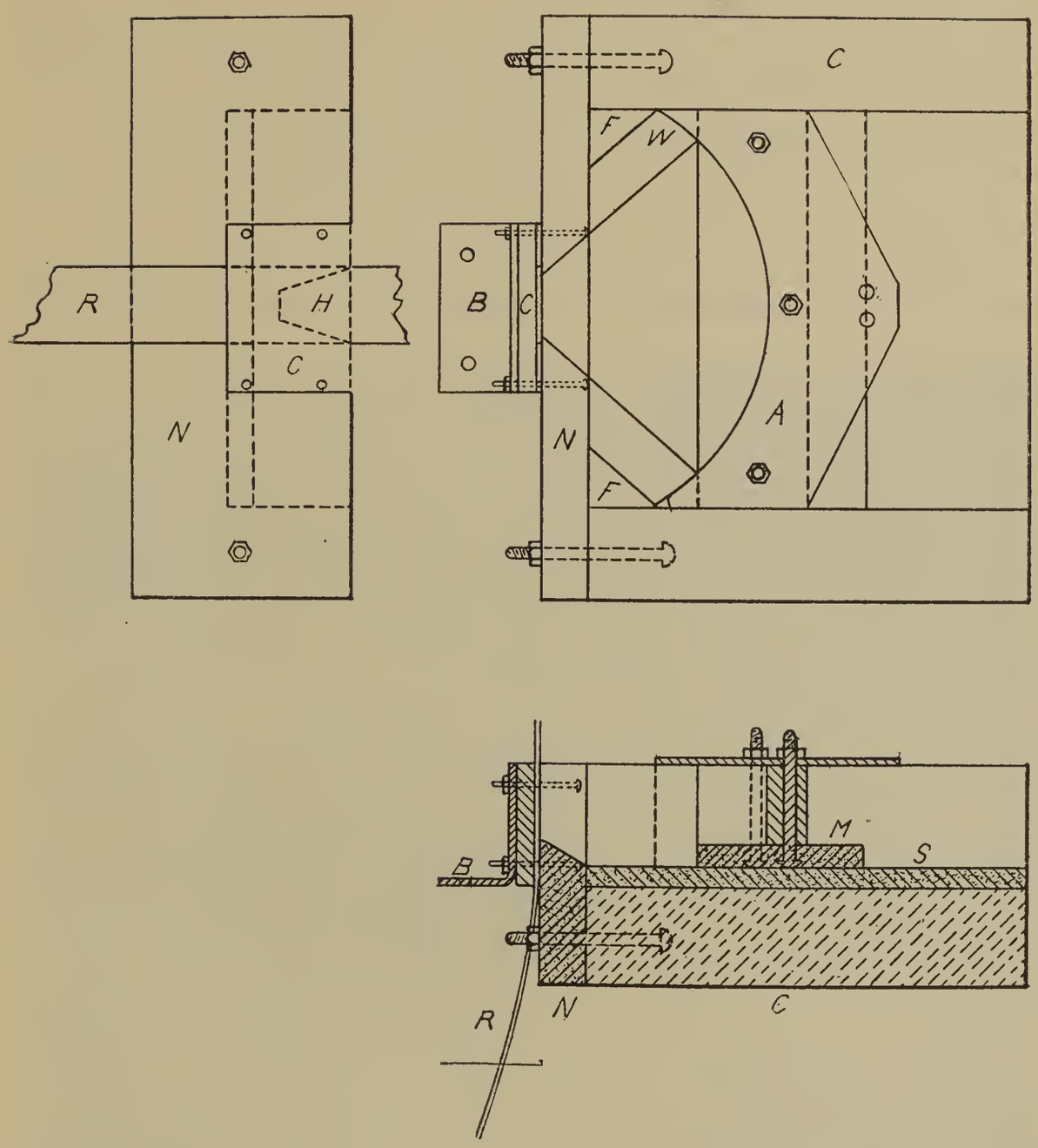


PLATE VI.

Electrolyzing Apparatus No. 3.

C—Portland cement casing.
N—Soapstone end.
S—Soapstone bottom.
W—Soapstone sides.
M—Soapstone base for anode.
A—Graphite anode.
H—Aperture in soapstone end N.
R—Iron ribbon as cathode, to slide between soapstone end N and iron block C.
B—Copper conductor fastened to iron block C.

Connections for apparatus same as for apparatus No. 2.

the end of an iron rod into the electrolyte to act as cathode without exposing a small portion of the side of the rod, as well as the bottom, to the electrolyte. Consequently more current will enter the edge, or side, of the rod, and hence a tendency for more calcium to deposit around the edge of the rod than directly on the flat end.

Cathode current density has been found to have an important effect upon the structure and nature of the deposit and hence upon current efficiency also. And it is a great objection to this "calcium rod" idea that nothing definite concerning the effects of current density can be determined, because, as the deposit grows the actual cathode surface is continually changing. However, since the current density is continually changing, the conditions under which a reguline deposit is formed are continually changed.

In regard to the use of iron rods of different diameters as starting cathodes, it may be stated that with the apparatus in hand it was found that if a rod much less than 1 cm. (3/8 inch) in diameter was used the current density and hence the heating effect was so great that calcium would not form in the solid condition, while if a much larger rod were used the deposit was very crystalline and irregular and mixed with $CaCl_2$ even near the base of the iron rod.

EXPERIMENTS WITH APPARATUS NO. III.

Before taking up the question of current efficiency and in view of the inherent faults in the design of the apparatus used up to this time, I shall describe an electrolyzing apparatus of my own design in which I have endeavored to overcome some of the difficulties.

In the design of this apparatus I have endeavored to attain the following:

1. An apparatus in which the anode and cathode surfaces shall be definite under all conditions.

2. To be able to vary the current density and note the effects upon the electrolysis.

3. To accomplish the removal of the deposit of calcium as

fast as formed without interfering with the uniformity of conditions.

4. Construction such that it would stand many "runs."

5. To confine the current to a definite amount of electrolyte, and to an invariable course through the same.

As in the preceding experiments 100 parts of $CaCl_2$ and 17 parts CaF_2 were fused down in a Battersea crucible by means of a resistance furnace and after being thoroughly mixed were

PLATE VII.

poured into the apparatus. Here, after first being thoroughly heated for some time with an alternating current (a carbon block was attached to the ribbon cathode in the opening H), the direct current was switched on and electrolysis started. As the metallic calcium deposited to a sufficient thickness the iron ribbon was gradually raised, presenting new cathode surface.

Paul Woehler states that in his experience electrolyzing $CaCl_2$ and CaF_2 by the Rathenau method that a cathode current density

of from 45 to 250 amperes per square centimeter can be used and a stick of calcium obtained. He based his figures upon the fact that the amount of current flowing through his apparatus was constant but the cross-section of the calcium stick varied at different parts. This is obviously a wrong basis upon which to come to such a conclusion, however. Nevertheless, my apparatus as first constructed had a cathode surface of such size that when sufficient current flowed to cause the whole bath to be in a well fused condition, there was a density of 45 to 50 amperes per square centimeter. The first two trials, however, proved that even this cathode current density is altogether too high, for the calcium would not deposit on the iron ribbon, but simply melted and floated about in the bath.

The cathode opening (A) was then made larger and other runs made. A run made when the electrolyte was in good condition showed that calcium came out in the best physical condition at about 10 amperes per square centimeter. (See photograph VII). To be sure, calcium will come out at a considerable higher current density, but under the particular set of conditions under which these experiments were performed the above current density was found to give the best results. At a lower current density the calcium carries up more $CaCl_2$ with it, which tends to solidify just above the surface of the bath and cause the iron ribbon to be cemented fast.

As will be seen from the photograph, if the calcium does not sufficiently alloy with the iron (which seldom happens), the two will break apart upon cooling some distance above the bath on account of difference in rates of contraction of the two metals. When the calcium does alloy with the iron ribbon, the latter expands at these places, giving rise to little "hills" in the ribbon. Examination of the iron at these points after removal of the calcium shows it to be softer and rotten.

Anode current density is not of so great importance as is cathode current density. We simply need sufficient anode surface over which the $CaCl_2$ bath can fuse as far as it likes with the given current in use. If the anode density is unduly great, arcing or glowing phenomena take place at the junction of the carbon and fused bath increasing the total resistance offered by the cell.

CURRENT EFFICIENCY.

While the current efficiency at which calcium can be reduced from its chloride is of great importance from an engineering standpoint, yet if the exact conditions under which such efficiency is obtained and can be maintained are not known, the figures have lost much of their value. Still, although we do not understand fully the nature of the process, to know what efficiency can be attained at times is interesting and encouraging.

Both Goodwin and Woehler made current efficiency determinations, and not only their results, but also their methods of determining them were very different. Goodwin determined the current efficiency for a run of several hours duration using only $CaCl_2$ as electrolyte. He separated the metallic calcium from the $CaCl_2$ by pounding loose the encasing $CaCl_2$ which had solidified about the "rod" of calcium. The calcium thus mechanically separated was weighed and the efficiency figured. His highest efficiency was 40 percent.

On the other hand Woehler, who electrolyzed 100 parts of $CaCl_2$ and 17 parts of CaF_2, made a mark on the forming calcium rod at the level of the bath, electrolyzed five minutes (gradually raising the rod) and made another mark at the level of the bath. This section was cut out after the run, and dissolved in a weak acid solution, the hydrogen collected and from this the amount of calcium computed. He claims an efficiency of 82.2 percent. While Woehler would probably obtain a higher current efficiency than Goodwin by employing a mixed electrolyte, yet the method of Woehler is open to criticism.

Goodwin's method gives us the efficiency for the actually available metallic calcium, while Woehler's efficiencies are too large, because, from my description of the nature of the deposited calcium, much of the metal was in a non-available form; that is, so intimately mixed with $CaCl_2$ that it would be almost impossible to separate it mechanically or otherwise.

The method which I used in determining current efficiency was that of Goodwin, but I had to be very careful to completely break up the deposit in order to be sure that all of the $CaCl_2$ was eliminated, for the specific gravity of the latter is so much higher than that of the metal as to very appreciably raise the

apparent efficiency. Some of the pieces were even boiled in alcohol (anhydrous) in order to facilitate the removal of the $CaCl_2$.

The following four results, the best obtained, are submitted, all of which are for baths of 100 parts pure $CaCl_2$ and 17 parts CaF_2.

Apparatus No. 3

No. 1. Current, 76.4 amperes; time, 70 minutes; current efficiency, 67.65 percent.

No. 2. Current, 51.5 amperes; time, 57 minutes; current efficiency, 75.6 percent.

No. 3. Current, 45 amperes; time, 12 minutes; current efficiency, 84.6 percent.

No. 4. Current, 70 amperes; time, 10 minutes; current efficiency, 93.3 percent.

CHEMICAL CHANGES IN ELECTROLYTE.

On page 133 was described the action of the bath during electrolysis both when water was present and when the bath had been previously dehydrated. If the bath had been thoroughly heated for some time previous to the passage of the direct current, calcium was formed quite readily, other conditions being favorable. Now it will be remembered that the dehydration proceeded with the following successive results after the application of the heat to the $CaCl_2 + H_2O$: Firstly, steam came off; secondly, HCl fumes, then bubbles of hydrogen appeared all over the bath and lastly only the yellow flames remained. As stated before, these yellow flames were never gotten rid of entirely under any conditions. They exist only in the very hottest part of the bath, *i. e.*, at the cathode if direct current is used, and if alternating current is used only at the smaller electrode. For the most part they appear to be burning hydrogen, but no doubt some other substances are present also.

In view of the fact that it is almost impossible to get such data as would give an exact insight into the chemical composition of the bath, I can give only my belief as to what actually occurs. And in this I am influenced by the views of Woehler, who has made similar observations. Woehler claims that after the temperature of the bath has reached a certain value the

H_2O which still remains begins to combine with the $CaCl_2$ according to the following equation: $CaCl_2 + H_2O = Ca \begin{matrix} -OH. \\ -Cl. \end{matrix}$

This compound releases water with difficulty, and furthermore during electrolysis would probably react with the metallic calcium to form anhydrous oxychloride and hydrogen. This theory, while worthy of close consideration, does not explain why hydrogen bubbles and the yellow flames come off during the heating with alternating current. Nevertheless, the above equation probably states the condition of affairs somewhere nearly right. So far as the whole truth is concerned we need much more data of a kind which is very difficult to get.

It is a well known fact, that if in the electrolysis of NaCl, the temperature of the electrolyte becomes too high the sodium will re-dissolve in the electrolyte to form a hypothetical subchloride, and but little sodium will be obtained no matter how high the current density may be.

Such an assumption has been made by some regarding the electrolysis of $CaCl_2$: $CaCl_2 + Ca = 2CaCl$.

Richard Lorenz has shown that lead and zinc will dissolve in their respective chlorides if the temperature is raised to a certain value. The three factors upon which the phenomenon depends are given as follows: "Temperature of bath, volatility of the metal, and its solubility in the bath." He further states that this "metalnebel," metallic cloud, as he terms the dissolved metal may be either (a) a real solution of the metal in its fused haloid salt, or; (b) a mere pulverization of it in suspension. He prefers the former view.

I have called attention to the fact that those portions of the bath through which a direct current had passed for a considerable time were colored black. A piece of this black $CaCl_2$ was found to decompose water, liberating hydrogen and forming a white precipitate of $Ca(OH)_2$ suspended in a clear solution, but leaving no black residue. This showed that the coloration of the $CaCl_2$ was not due to the disintegrated carbon but to either finely divided metallic calcium or the subchloride.

Since $CaCl_2$ is soluble in alcohol (anhydrous) and metallic calcium is not, a piece of the solidified electrolyte was placed in this solvent with the result that the $CaCl_2$ was dissolved and

a finely divided deposit formed at the bottom of the test-tube. The alcohol was poured off and some water then poured on the precipitate. Hydrogen immediately began coming off quite briskly. A drop of H_2SO_4 was next added to the solution and instantly the whole black precipitate was changed to snow white $CaSO_4$, and the heat developed from the reaction was sufficient to cause the ignition of the hydrogen liberated.

The two experiments just described do not prove absolutely that the dark particles are metallic calcium instead of CaCl; but from the physical qualities, as metallic appearance and specific gravity observed, it was concluded that these particles must exist as finely divided calcium mechanically suspended in the bath when the latter is solidified.

Now from analogy it is very likely that calcium dissolves to some extent in $CaCl_2$ at a high temperature the same as lead or zinc have been found by Lorenz to dissolve in their respective chlorides. However, there are grounds to believe that the solution of calcium in $CaCl_2$ ought to be regarded as taking place in a manner exactly parallel to the solution of $CaCl_2$ in H_2O, rather than to assume that a sub-chloride is formed. As such a compound has never been formed under any conditions by anyone so as to be recognized as a definite chemical compound, surely there is no reason to state without any qualifications that such a compound is formed in the electrolysis of $CaCl_2$. If we assume that the calcium is really soluble in the $CaCl_2$ while the latter is at a high temperature as stated, we can also naturally infer that as the $CaCl_2$ cools down that the solubility of the calcium in $CaCl_2$ decreases and hence crystallizes out as it were.

In discussing the effects of dissolved metallic zinc or lead in their respective chloride baths which are undergoing electrolysis, Lorenz states that the metal acts as a depolarizer, and further, that no metal will be deposited at the cathode until the bath has become saturated with the metal.

To be sure there is some depolarization occasioned in the case of calcium also, but whatever may be the state of affairs for zinc and lead, it is certain that Ca can be deposited from a $CaCl_2$ bath before it is saturated with the metal. This fact was proved while obtaining the decomposition voltage curves which follow. The electrodes used were two inches apart and placed in a $CaCl_2$

bath which had never been electrolyzed before. There was much molten $CaCl_2$ surrounding the electrodes and plenty of chance for circulation of electrolyte between electrodes. In several of these determinations of decomposition voltage, easily recognizable deposits of calcium were obtained, although the current used was small and the duration of its passage only a few minutes at a time. Indeed that most of the curves have well defined "knees" in them is sufficient proof of the fact. Curve II was taken for a $CaCl_2$ bath which had metallic calcium suspended in it from previous runs, and it will be noticed that there is no well defined "knee" in the curve.

DECOMPOSITION VOLTAGE CURVES.

As just intimated the study of the decomposition voltage curves which would be obtained under various conditions would throw much light on the best chemical composition of the bath as well as best physical conditions, correct temperature, etc., at which the electrolysis ought to be carried on for most successful results. Although prevented by lack of time and the necessary pyrometer for determining temperatures, experiments along this line were not carried on as far as desirable. However, a few results have been obtained which are of at least some value. On Plate VI is shown a diagram of the apparatus used, and on page 138 a description and data concerning same.

Details of electrodes for obtaining decomposition voltage curves are shown on Plate VIII.

It must be borne in mind that the value of the decomposition voltage for a fused salt will depend not only upon the chemical composition of the electrolyte and its temperature, but also upon the nature of the electrodes used and to a *slight extent* upon their geometrical disposition with respect to each other.

In the experiments carried out a $CaCl_2$ electrolyte only was used and in each case the data taken for the curve when the bath had just reached a nicely molten condition.

Curve No. II was obtained with an anode of graphite and a cathode of polished sheet iron, each 2.5 cm. (1 inch) square and separated 2.5 cm. (1 inch). After the current had been passed and the data obtained the electrodes were removed and examined.

The anode, of course, was unchanged; while the cathode showed no deposit of Ca, or any Ca-Fe alloy; it was appreciably corroded. By extending the resistance line we get 2.04 volts as the decomposition voltage.

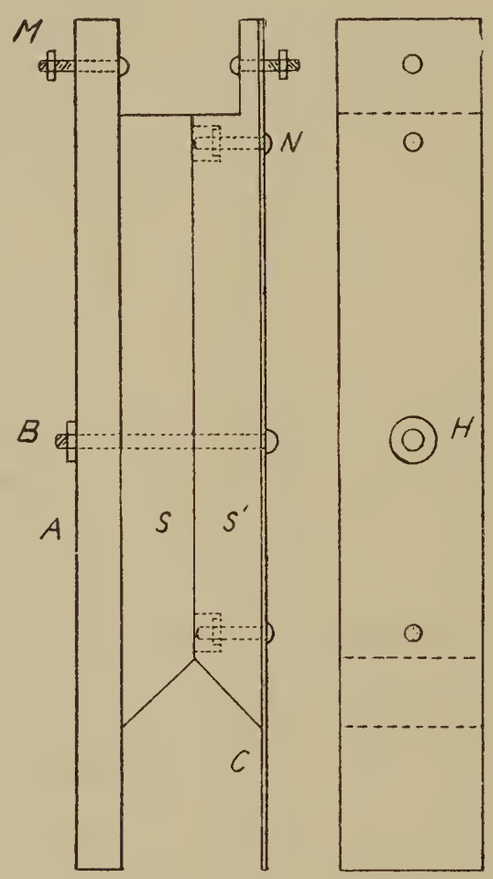


PLATE VIII.

A—Graphite anode.
C—Iron cathode.
H—Large hole through iron cathode.
S and S'—Soapstone separators.
M—Binding screw.
B—Bolt for holding pieces together.
N—Bolts for holding iron cathode to support S'.

Practically the same conditions were maintained in getting data for curve No. III, except for a slight increase of temperature as evidenced by the slope of the resistance line of the latter curve. The critical voltage for this curve is about 2.85 volts. An examination of the cathode after the run showed it to be covered with a thin bright deposit of calcium which decomposed water.

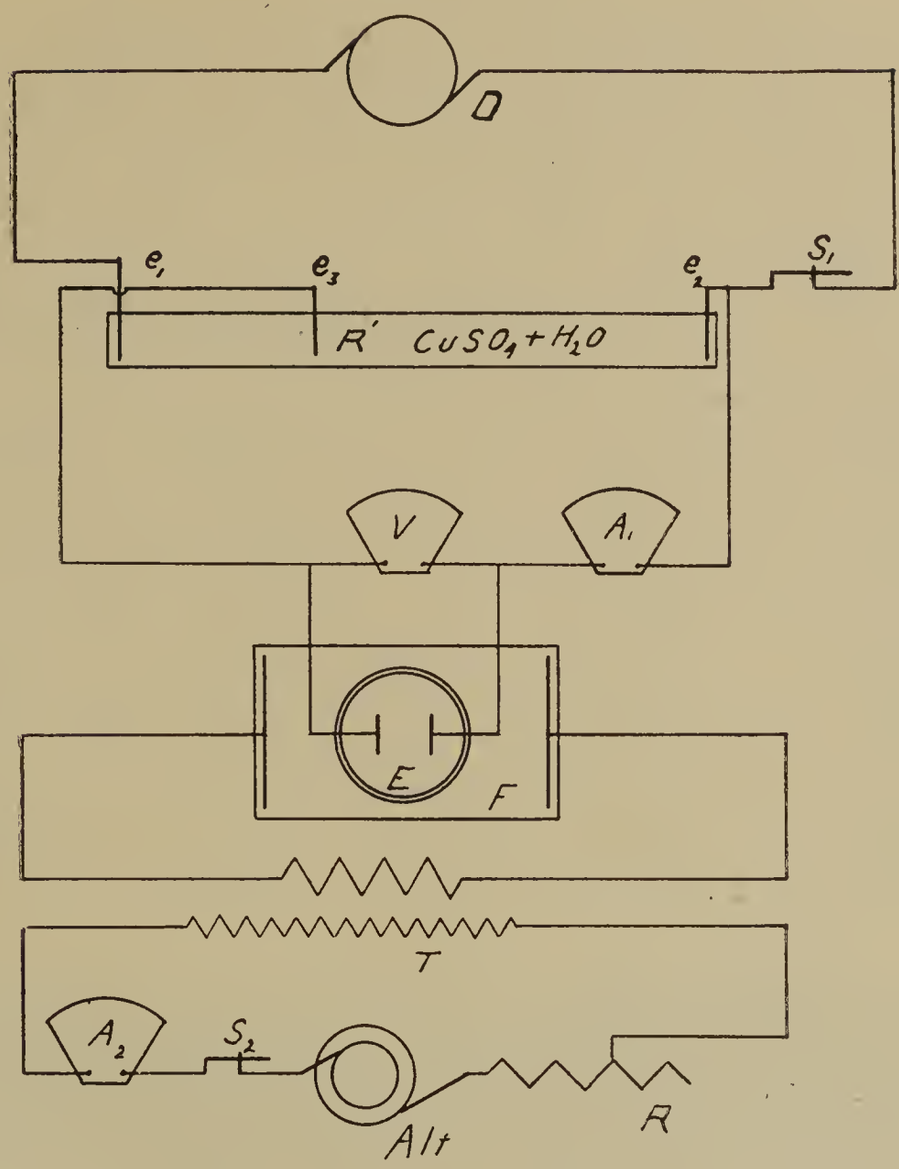


PLATE IX.

Showing disposition of apparatus for obtaining decomposition voltage curves.

E—Electrodes in $CaCl_2$ in Battersea crucible.
R^1—Liquid rheostat provided with three electrodes, e_1, e_2, e_3.
S—Switch.
D—Direct current dynamo.
V—Low-reading Weston voltmeter.
A_1—Low-reading Weston ammeter.
T—Step-down transformer.
A—Ammeter.
S_2—Switch.
Alt.—Alternator.
R—Rheostat.

After the calcium was dissolved off the iron was left in a soft corroded condition. No doubt an alloy was formed with the iron at its surface.

As previously explained, curve No. I was obtained for a bath which had been previously electrolyzed and contained much metallic calcium in the electrolyte. If we extend the very flat resistance line to the Y axis we obtain 2.62 volts as the decomposition value.

Curve No. IV shows a very steep resistance line due to the fact that only the tip ends of the electrodes were immersed in the molten electrolyte. The electrolyte was pure $CaCl_2$. Extension of the resistance line shows a critical voltage of about 2.65.

Since in many of the experiments performed calcium seemed to possess the power of forming a superficial alloy with the iron cathode, this fact may help to lower the critical voltage. (Theoretical 3.727). If we could employ two electrodes which would be entirely inert toward the products of electrolysis and the electrolyte, we might reasonably expect to get results agreeing fairly closely with the theoretical value, if from this we also subtracted the voltage corresponding to the heat supplied to the $CaCl_2$ to raise it from the ordinary temperature to the fusion point. This latter step is necessary since the heat of formation is given for solid $CaCl_2$.

However, the above values are probably approximately correct for electrodes of graphite and iron,—the two electrode materials which would be used in the electrolysis of $CaCl_2$ on an industrial scale.

DATA FOR DECOMPOSITION VOLTAGE CURVES.

Curve No. I.

Graphite anode 2.5 cm. (1 inch) square. Iron cathode 2.5 cm. (1 inch) square. Electrodes separated 2.5 cm. (1 inch). Bath of $CaCl_2$ had previously been electrolyzed.

Volts	*Amperes*	*Volts*	*Amperes*
0.433	0.05	2.300	1.30
0.560	0.10	2.330	1.40
0.600	0.10	2.330	1.50
0.717	0.10	2.434	1.60
0.966	0.20	2.535	1.75
1.233	0.35	2.567	1.91
1.466	0.50	2.567	2.00
1.734	0.60	2.567	2.15
1.834	0.80	2.660	2.55
2.067	0.95	2.660	2.80
2.167	1.20	2.660	3.20

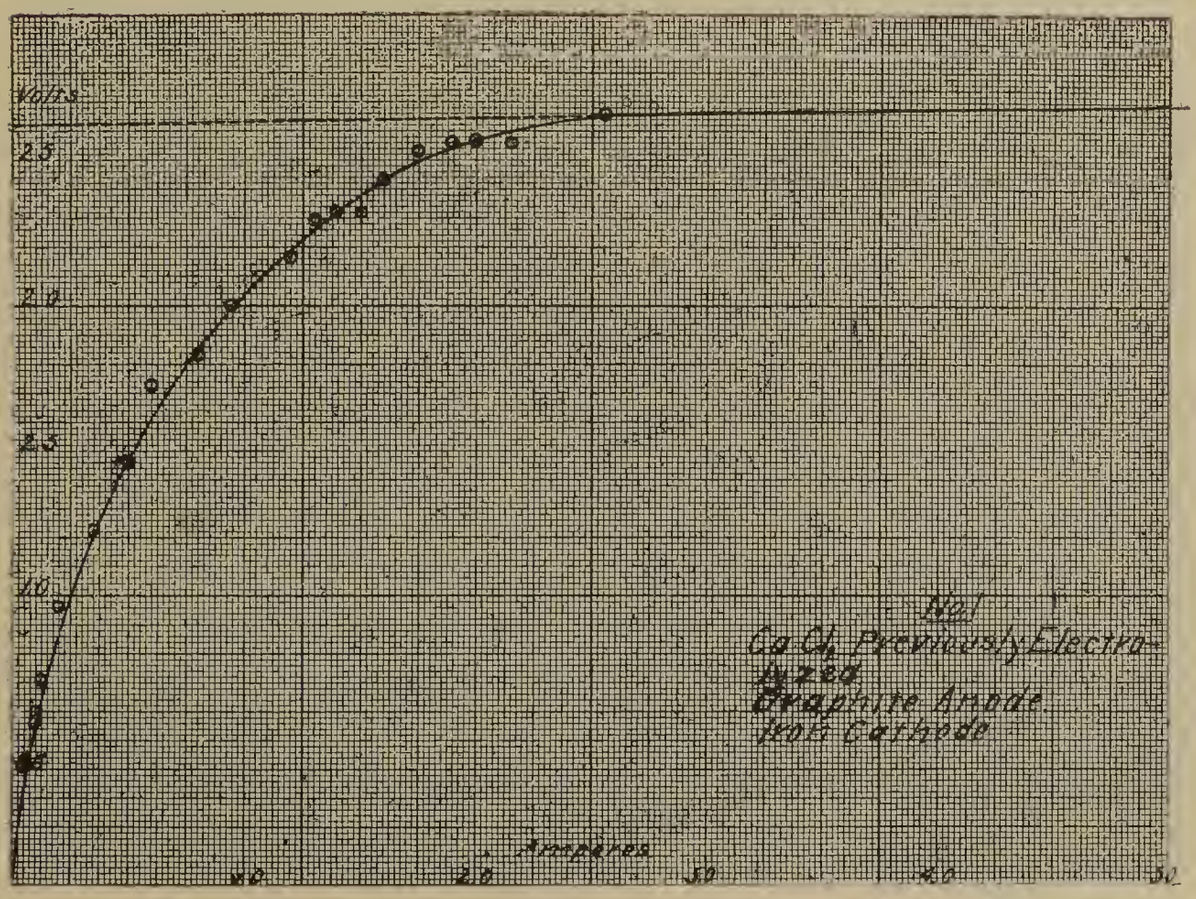


PLATE X—CURVE NO. I.

DATA FOR DECOMPOSITION VOLTAGE CURVES.

Curve No. II.

Graphite anode 2.5 cm. (1 inch) square. Iron cathode 2.5 cm. (1 inch) square. Electrodes separated 2.5 cm. (1 inch). Pure $CaCl_2$ electrolyte.

Volts	*Amperes*	*Volts*	*Amperes*
0.10	0.025	2.7	1.3
0.40	0.10	2.7	1.35
0.65	0.15	2.725	1.55
0.95	0.25	2.95	1.95
1.1	0.45	3.15	2.35
1.5	0.80	3.30	2.75
1.75	0.85	3.40	3.20
1.85	1.05	3.70	3.90
2.2	1.10	3.80	3.95
2.6	1.20	4.10	4.30
2.7	1.25	4.20	4.50

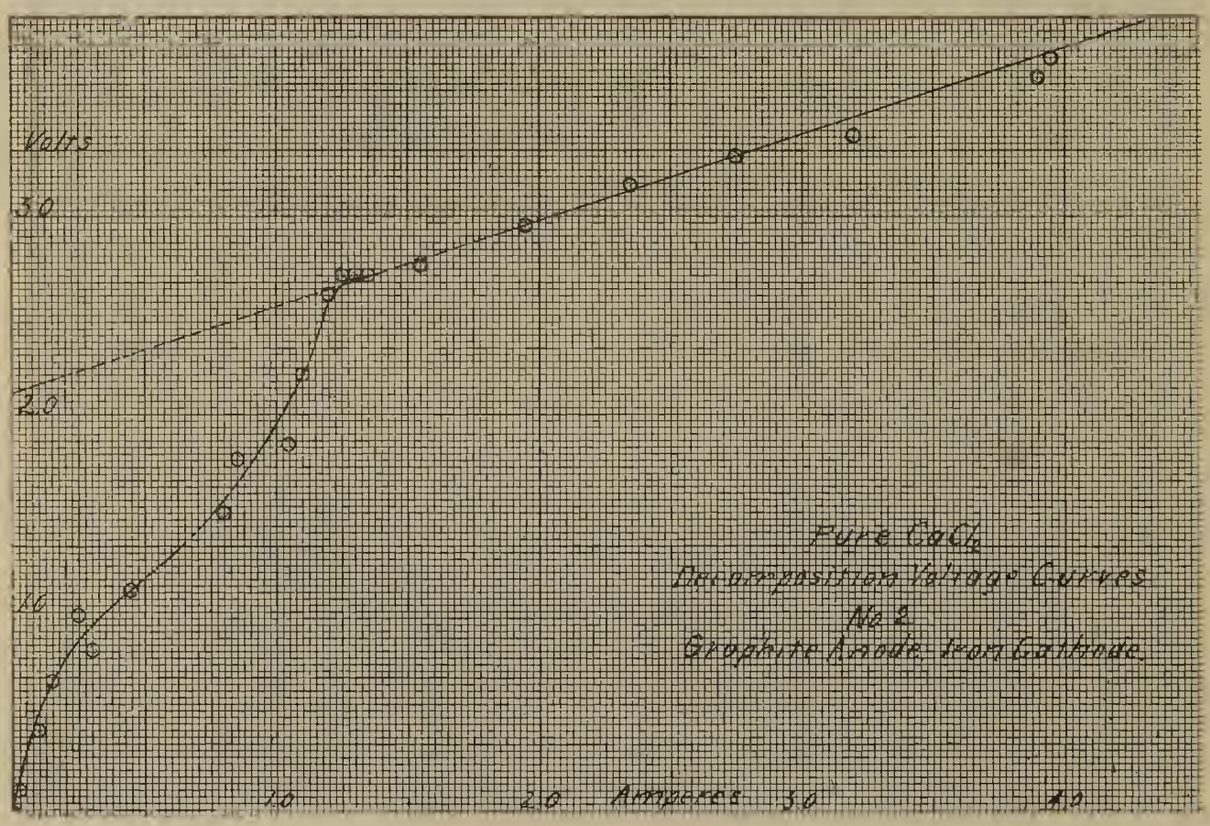


PLATE XI—CURVE NO. II.

DATA FOR DECOMPOSITION VOLTAGE CURVES.

Curve No. III.

Graphite anode 2.5 cm. (1 inch) square. Iron cathode 2.5 cm. (1 inch) square. Electrodes 2.5 cm. (1 inch) apart. Pure $CaCl_2$ bath.

Volts	*Amperes*	*Volts*	*Amperes*
0.95	0.10	3.05	1.15
1.25	0.25	3.05	1.40
2.00	0.60	3.25	2.20
2.70	0.60	3.30	3.4
3.00	0.90	3.75	4.15
3.00	1.00	3.90	5.00

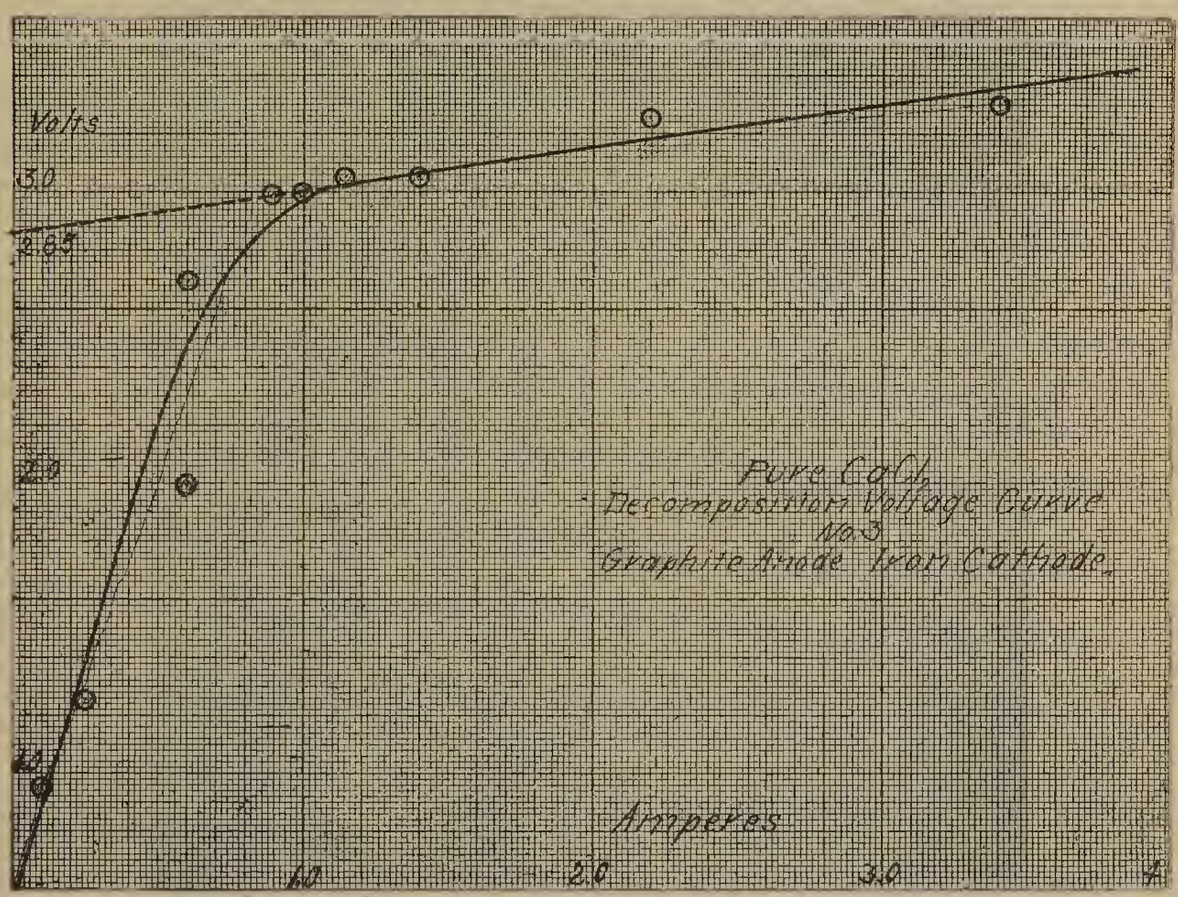


PLATE XII—CURVE NO. III.

DATA FOR DECOMPOSITION VOLTAGE CURVES.

Curve No. IV.

Graphite anode and iron cathode. Only tip ends immersed in pure $CaCl_2$ bath. Electrodes 2.5 cm. (1 inch) apart.

Volts	*Amperes*	*Volts*	*Amperes*
0.30	0	2.15	0.05
0.44	0	2.45	0.05
0.55	0	2.75	0.06
0.70	0.025	2.90	0.10
0.81	0.03	3.10	0.13
1.05	0.03	3.25	0.20
1.10	0.03	3.50	0.24
1.45	0.04	3.65	0.35
1.755	0.04		

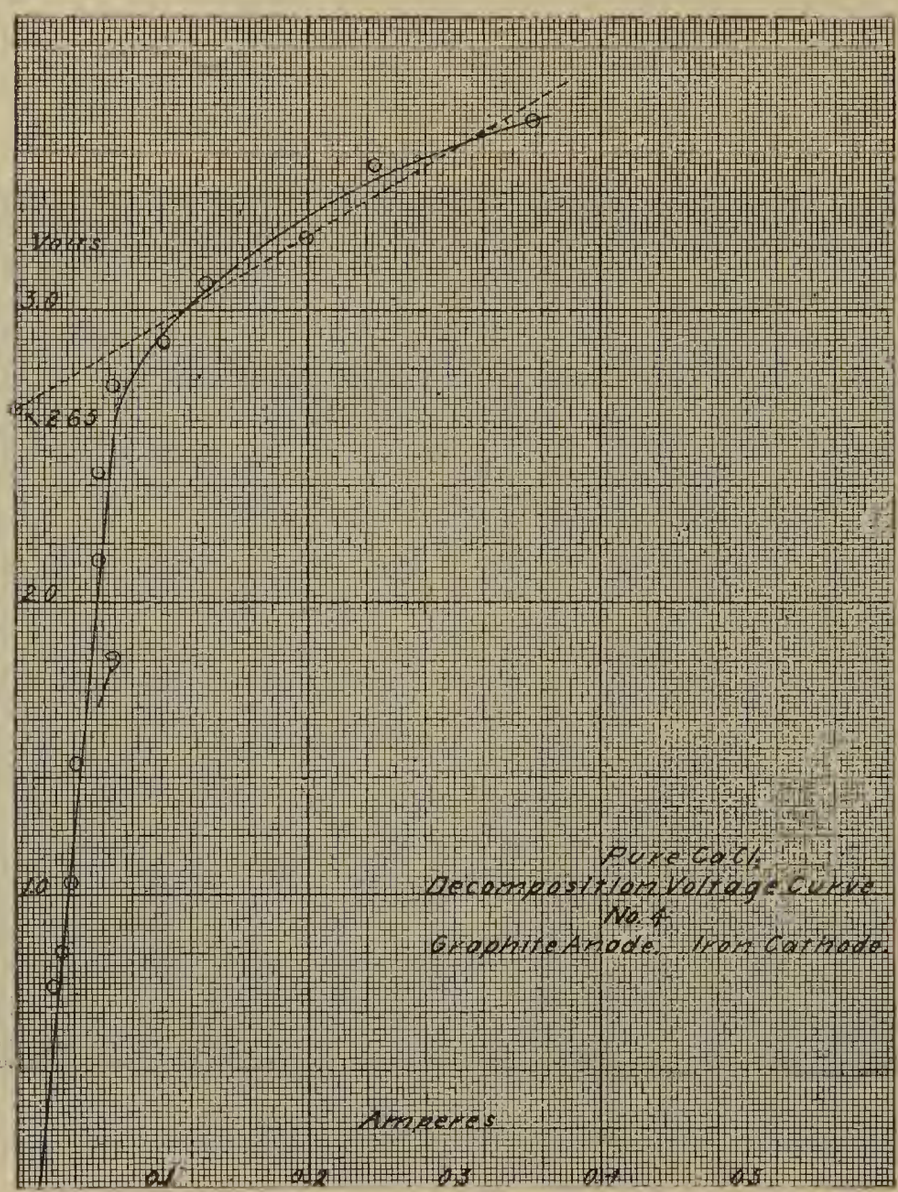


PLATE XIII—CURVE NO. IV.

DISCUSSION.

MR. CARL HERING: It would be interesting to know what the commercial efficiency is of the production of calcium in some such figure as the pounds per kilowatt hour. The ampere hour efficiency, of course, is a matter of technical interest, but it does not give us that which is of interest commercially.

MR. JOHNSON: I obtained about 500 grams of calcium in all, at the rate of from 20 to 60 grams per short run of an hour. In runs this short it is very hard to determine how the process would work out commercially.

MR. F. C. FRARY (*In part Communicated after the meeting*): Since the author of this paper has condemned that apparatus which he designates as the Rathenau type, and since this apparatus has been successfully used commercially at Bitterfeld, and we have had some satisfactory experience with it at the University of Minnesota, I should like to point out what appears to me to be the reasons for the poor results which Mr. Johnson obtained.

In the first place, Mr. Johnson used altogether the solid rod cathode of Goodwin, although Tucker and Whitney[1] showed, in January, 1906, when Mr. Johnson was working on this subject, that it was much better to use a water-cooled cathode of iron pipe. In my opinion, much of the trouble which Mr. Johnson had in getting a solid stick of metal was due to this, and the rest to poor manipulation. According to his statement on page 130, the metal which formed was not drawn out of the electrolyte properly, but was allowed to grow over to the anode. In the next paper I shall take up more in detail the method of controlling the character of the metallic rod by the rate of its withdrawal from the electrolyte.

Regarding the five defects of this type of apparatus, pointed out on the same page, I would suggest that they are mostly defects of the particular apparatus in hand, and not of the type. Taking them up in the order given, I cannot reconcile the first statement with what the author says a little later, that after trying various sizes of cathode on an anode vessel of the same size, he decided that a rod 1 cm. (3/8 in.) in diameter was the best. As near as can be told from the diagram, this was what he used in the first apparatus which he criticises.

[1] J. Am. Chem. Soc., **28**, 84 (1906).

Regarding his second statement, there is no excuse for short circuits if the metal is withdrawn at the proper rate, as the spongy portions should never be allowed to extend more than 6 mm. (¼ in.) from the rod at the most.

The disintegration of the upper part of the crucible is very simply prevented by keeping the crucible nearly full of the electrolyte. Enough spatters up at the edge on account of the violent evolution of chlorine to cover any exposed places in a short time. The outside of the crucible may be easily protected by a layer of cement and carborundum fire-sand, or probably by cement and ordinary sand.

We have had no trouble with cracking of the crucible except when it has been allowed to stand idle for a long time. Then it sometimes cracks. Once we electrolyzed some molten barium hydroxide, and found that after the crucible had cooled and stood a few days, the melt swelled and took up water, opening up cracks about 12 mm. (½ in.) wide in the crucible. I am therefore inclined to believe that the cracking of the crucible which Mr. Johnson observed in the use of calcium chloride is due to the presence of an excessive amount of lime in the bath, this being formed by the burning of the spongy metal which he had formed but could not remove.

I heartily agree with the fifth criticism. In the paper published by Mr. Badger and myself[2] we showed that corrosion of the copper bands could be reduced by copper-plating the lower part of the outside of the crucible, and in the following paper I will show a still better way of meeting this objection.

With regard to Mr. Johnson's improved anode crucible, I should like to criticise the use of soapstone or any silicate in a vessel intended to hold fused calcium chloride. Arndt[3] has shown that fused calcium chloride at 900° is capable of dissolving about 14 percent of lime or about 5 percent of silica. A silicate would probably be as soluble as the lime. On page 134, and again on page 139, Mr. Johnson speaks of heating the molten chloride to a high temperature for some time by means of an alternating current, so I presume that he managed to contaminate the melt with a good deal of dissolved soapstone. As metallic calcium reduces silica, he would get quite a little calcium silicide with his

[2] Trans. Am. Electrochem. Soc., **16**, 185 (1909).
[3] Z. Electrochem. **15**, 784 (1909).

metal. The practice of melting the electrolyte in a battersea crucible is also calculated to introduce silicious impurities.

With regard to the gases evolved during the heating of the electrolyte, I would suggest that they are probably mostly CO and CO_2. It is well known that calcium chloride on evaporation and dehydration is partly decomposed into the oxide, and that this readily takes up CO_2 from the air. Samples melted down in this laboratory by Mr. Badger and myself have been found to contain from 0.6 to 1.4 percent CaO and from 0.12 to 0.6 percent $CaCO_3$. Further, we have experimented with solutions of lime in molten calcium chloride, and found that they absorb CO_2 readily below 1000° C., but that at about this temperature they begin to be decomposed, large bubbles of gas (CO or CO_2) being given off. It appears, however, to be impossible to drive off all the CO_2 by simply heating, though analyses of melts which have been electrolyzed for some time show the presence of only traces of carbonates. Mr. Johnson notes that the persistent gas bubbles always appear around the smaller electrode, where, of course, the temperature is the highest. We have noted this same phenomenon, and I believe it to be due chiefly to the reduction of the $CaCO_3$ either by Ca or C, forming CO and CaO. In the cooler parts of the electrolyte, where there is CO_2 from the combustion of the graphite and the CO, the dissolved CaO would be reconverted to the carbonate. Some idea of the amount of carbonate which may be contained in a molten mixture of CaO and $CaCl_2$ may be obtained from the following data: A sample containing 12.7 percent CaO held in addition 5.8 percent $CaCO_3$, one with 9.9 percent CaO held also 4.1 percent $CaCO_3$, and many samples with 6 to 7 percent CaO had also 2 to 3.8 percent $CaCO_3$. One sample with 6.1 percent CaO and 3.27 percent $CaCO_3$ was boiled at a high temperature for some time, and again sampled. The analysis now showed CaO 7.99 percent, $CaCO_3$ 0.3 percent, showing that the boiling had reduced the content of carbonate and increased that of oxide proportionally.

Weber[4] has shown that calcium chloride dried at 180° to 200° C. contains only 0.12 to 0.24 percent moisture, and it certainly seems improbable that it would obstinately retain an appreciable quantity at its melting point.

[4] Ber. **15**, 2316; J. Chem. Soc., **44**, 151 (1883).

I would like to ask if the black crisp mass mentioned at the bottom of page 134 was tested for carbide[5] or silicide of calcium? Under the conditions described it might be either of these. We have never had such a deposit with any bath.

Mr. Johnson's conclusions on page 135, concerning the tendency of the metal to precipitate in nodular or arborescent forms, are entirely correct, but indicate that he misunderstood the operation of the apparatus, as these should have been melted down to form a solid stick, as described in the next paper. Some years ago I saw some of the rods of metallic calcium produced at Bitterfield, and I am sure that they were all solid and showed no trace of the sponginess described by Mr. Johnson. When using the plain chloride electrolyte we have never had trouble with rods of metal solid in the center and spongy on the outside, as Mr. Johnson did. Occasionally in the earlier runs when the metal was not withdrawn fast enough there would be spongy spots extending clear through the stick and perhaps 6 mm. (¼ in.) along it, but in later runs, where more care was taken, the deposits were perfectly solid throughout. With the chloride-fluoride electrolyte we had more trouble, but were able to get solid rods by careful work. The fact that Mr. Johnson's rods were most solid near the iron cathode is probably due to the cooling effect of the latter, which enabled him to partly melt down the deposited metal without losing it. When the rod was longer, the cooling was not sufficient to enable him to melt down the metal on the end without melting so much that it dropped off and an arc was formed.

In the design of his Furnace No. III, I fail to see the advantage of keeping the anode surface constant under all conditions, so long as sufficient anode surface is exposed to prevent the "anode effect." The removal of the metal from the bath as fast as it is formed is, of course, the keynote of success, but this is apparently just what this apparatus does not do. On the average, we may consider the metal to be deposited half way between the surface of the bath and the bottom and compelled to remain in contact with the molten bath during the slow progress of the ribbon until it reaches the top, instead of being formed almost at the surface of the bath and very soon removed from it, as in the case of the Rathenau type of apparatus. And I must confess

[5] See Moissan, Compt. rend., **138**, 661; J. Chem. Soc., **86**, ii, 333 (1904).

that I cannot see any advantage in attaining Mr. Johnson's fifth object, "To confine the current to a definite amount of electrolyte and to an invariable course through the same," and would be obliged to him for an explanation of it.

To one who has not seen this apparatus in operation, it would seem difficult to prevent the bath from either solidifying around the lower part of the iron ribbon cathode and preventing its motion, or else, if kept molten, from running out of the space between the ribbon and the rest of the apparatus. In depositing the metal as a thin ribbon, Mr. Johnson is introducing needless complications by reason of the very large surface which his piece of calcium will have as compared to a cylindrical piece of equal weight, such as he would draw out with the Rathenau type of apparatus. The larger the surface, the greater will be the action of the metal on both the electrolyte and the air.

Inasmuch as we have made the same assumption as Woehler, that the current density at the cathode is approximately the quotient of the total current flowing by the area of the metallic rod, I should like to have Mr. Johnson explain why this is "obviously a wrong basis," considering the fact that in our experiments, and probably in Woehler's also, the metallic rod did not extend for any appreciable distance below the surface of the melt. If Mr. Johnson can find any better basis for measuring current density in such a case, we should like to hear of it.

In my opinion, however, the current density is of minor importance as compared with cathode temperature, *i. e.*, the temperature at the point of contact between the metal and the electrolyte. This conditions the solidity of the metal and is a function not only of the current density, but also of the rate of loss of heat to the cathode and to the rest of the melt. What Mr. Johnson means when he says that the current density of 45 to 50 amperes per sq. cm. was too high is that at that current density the cathode temperature in his apparatus was too high. The allowable and most satisfactory current densities are therefore constants of the particular apparatus used rather than of the process itself, as would be the case in the electrolytic refining of metals in aqueous solutions to which he refers. The lower current densities which he found it necessary to use in his apparatus are undoubtedly required because of the insufficient cooling of the cathode.

Referring to the black portions of the bath, mentioned on page 143, I would like to ask if this material which decomposed water might not have been either calcium carbide or an alloy of calcium with iron or silicon, introduced into the bath from the soapstone? The only black material which we have noticed in the electrolyte has been powdered graphite. If metallic calcium were appreciably soluble in the molten chloride at the temperature at which the electrolysis takes place, the violent convection currents would certainly sweep it over to the anode, where it would act as a depolarizer and materially reduce the current efficiency. That this is not the case under proper conditions is indicated by the high current efficiencies shown in the next paper.

As for calcium subchloride, it is to be noted that although Guntz and Basset[6] believed that their attempts to form it resulted only in mixtures of the chloride, oxide and hydride, yet more recently Woehler and Rodewald[7] appear to have prepared it in a state of approximate purity. It is, however, very probable that it is much more difficult to form it at the temperature at which the electrolysis of the chloride is accomplished than it is to form the analogous compounds of strontium and barium.

With reference to the determinations of the decomposition voltage of calcium chloride, I would like to call attention to the fact that this matter has already been investigated, and results similar to those obtained by Mr. Johnson have been published by Willner.[8] He showed, moreover, that while this result of 2.6 to 2.8 volts is obtained if cathodes of either iron, lead, tin or nickel are used, the use of a copper cathode gives a value of about 3.2 volts. To determine which of these values really represents the decomposition voltage of calcium chloride, he measured the e. m. f. of the cell $Ca/CaCl_2/Cl_2$, using a stick of metallic calcium as one electrode and a carbon rod saturated with dry chlorine as the other. These dipped into molten calcium chloride and were separated by a porous diaphragm. The cell thus prepared showed an e. m. f. of a little over 3.2 volts, and we are thus led to conclude that this is approximately the decomposition voltage of calcium chloride rather than 2.6 to 2.8 volts, as indi-

[6] Bull. soc. chim., (3) **35**, 404; J. Chem. Soc., **90**, ii, 540 (1906).

[7] Z. anorg. Chem., **61**, 54; C. A., **4**, 2078 (1910).

[8] Willner, Dissertation, Berlin 1907; Arndt and Willner, Z. Elektrochem. **14**, 216 (1908).

cated by Mr. Johnson's figures. This figure 3.2 represents the actual voltage required in the preparation of metallic calcium, since, soon after starting the process, the iron cathode becomes covered with a layer of the metal, and we have then a cathode of metallic calcium and an anode of carbon saturated with chlorine.

MR. JOHNSON: This work was done more than four years ago. Mr. Frary refers to work on decomposition voltages, which, in a way, is very similar to that I did. The results are nearly identical with mine.

MR. FRARY: Except that he has shown that, as Mr. Johnson surmised, the results obtained on an iron cathode are actually in error, and that the true decomposition voltage is about 3.2 instead of 2.6 volts.

MR. JOHNSON: Now, as to the black mass: It is well known that nearly all metals in a finely divided state are black, so that simply because that mass looked black is no sign it was finely divided carbon or graphite. I proved absolutely it was not carbon, and not calcium carbide. Acetylene is readily distinguished by its odor, and there was no odor of acetylene from the gases evolved. As for the protection of a crucible or electrolyzing apparatus by coating the sides over with copper electroplating, it is not practicable, because copper usually oxidizes in the air. I found it absolutely necessary to surround my crucible with asbestos cement and put over that iron or some protecting metal, and even then I found it soon went to pieces. I expected the ribbon would stick, but I found that by gradually moving the ribbon up, I never had any trouble. Even if the calcium chloride does become too fluid and starts to trickle down between the ribbon and the block, which it never does if there is any kind of workmanship used in making the block, it will solidify long before it gets anywhere near to the bottom of the block. Furthermore, that block is exposed to the aid on the outside and has a tendency to radiate a great deal of heat and so keeps cool, giving me really a cold cathode just as if cooled with water.

MR. FRARY: Now about the soapstone layer back of that iron ribbon?

MR. JOHNSON: There was no soapstone back of the block. The soapstone came up to the sides in bowl shape on the bottom

and right up to the iron block. The calcium chloride was usually fused on the sides of the container right up to the iron block and only the face of the ribbon was exposed to the bath, the calcium being deposited directly upon the ribbon. Suppose the calcium was deposited at the bottom of that trough, what difference would that make—it is acting as a cathode surface?

Mr. Frary: Mr. Johnson misunderstood about the copper plating. The copper was not plated on the whole of the outside of the crucible, but only on the water-cooled lower end where the contact was made. We protected the upper part of the crucible with a jacket of cement and carborundum fire-sand.

Mr. A. R. Johnson (*Communicated*): It appears as though Mr. Frary labored under various misapprehensions when he read my paper on calcium and later worked up his long criticism of the same. The greatest of his delusions was that I "condemned wholesale," as it were, the Rathenau type of apparatus. A term of milder and more limited meaning should have been chosen by Mr. Frary, I am sure. In no sentence in my paper have I "condemned" the type in general, but in many places I have pointed out *special* difficulties—such difficulties of operation and defects in apparatus design as any person would very probably encounter on attempting to work the process without having previously taken a post-graduate course in the art at Bitterfeld. A process is not necessarily condemned beyond redemption when special difficulties are pointed out.

Until Mr. Frary's next paper appears, on the "Method of Controlling the Character of the Metallic Rod by the Rate of Withdrawal from the Electrolyte," I shall feel that such parallel statements as the two following are most assuredly worth the serious consideration of anyone contemplating taking up the method:

Mr. Frary (this volume, page 118, paragraph 3): "It (calcium) also gave trouble by growing toward one side or other of the crucible, causing an increase of current at that point, with consequent increased growth of metal and a higher temperature, until finally the calcium on the edges would melt, and, being connected with the main stick only by thin pieces of metal, would

be easily swept away by the electrolyte." Mr. Johnson (this volume, page 135, paragraph 2): "My experiments have shown that whether the metal comes out with a coarse crystalline structure (as it usually does) or in a compact, dense form, the deposit cannot form to any great thickness before becoming nodular on the surface, or even growing out in arborescent forms."

Many of the troubles mentioned by me will, I believe, be encountered by anyone who works with the Rathenau apparatus of any dimensions whatever, but they are greatly aggravated by the use of small electrolyzing apparatus. Apparatus No. 1, with which I first worked, was only between three and four inches (7.5-10.0 cm.) internal diameter. Mr. Frary presumed too much in assigning dimensions to my apparatus. I gave no scale for the drawing. Apparatus No. 2 was fully twice the internal diameter of apparatus No. 1.

If the walls of a carbon-tube container for the calcium chloride are relatively thin they are very liable to crack when the fused bath cools down, even though the contents shrink, for the substance will often cement fast to spots here and there over the surface of the carbon. On the other hand, if the walls are made quite thick they may withstand the strains of the solidifying bath even though the latter expands somewhat. For general durability and ease of construction I am still inclined to look upon apparatus No. 2 as an improvement over No. 1.

The barium hydroxide incident appears to me to be rather far-fetched.

In regard to Mr. Frary's criticism of the use of soapstone, I may state that my apparatus was used from 2 to 6 times per week from the latter part of February to the 10th of May, in which time the stone was only slightly etched. It was soon learned that fairly definite relations held for the volume of electrolyte and its temperature and the amperage sent through the cell; and that the stone side-pieces and bottom of the cell were often needlessly exposed to very hot fused calcium chloride. Even though some silicates should become dissolved in the course of long usage of the apparatus the whole matter of the effect of small quantities of dissolved silicates on the actual yield of calcium is one of conjecture as yet.

Also the figures given by Mr. Frary on the solubility of lime,

carbon dioxide and calcium chloride are very interesting in themselves, but what harm, if any, do they do under the *actual working conditions* that prevail in the preparation of calcium? Mr. Frary appears to doubt the probability of water remaining bound to calcium chloride at high temperatures, but readily entertains the idea of the presence of carbon dioxide and carbonates in the bath at the electrolyzing temperature of 800°-900°. To me the one appears about as probable as the other, and, furthermore, while we know positively that but very little calcium can be gotten unless the calcium chloride is thoroughly dehydrated, the effect of carbon dioxide that *might* be absorbed by the bath at its surface *from the air when cold,* or *when fused at 800°-900°,* is indeed a matter for speculation only.

In asking for an explanation of the sentence in my paper beginning, "To confine the current to a definite amount of electrolyte and to an invariable course through the same," Mr. Frary, no doubt, sees fit to compel me to admit the obvious fact that a piece of calcium chloride is not an electrolyte until it is fused, and that wherever there is electrolyte there must be current. But which comes first, the current or the electrolyte? Let us substitute the word "bath" for "electrolyte." We now come back to the relation of amperage to volume of bath fused, the latter's average temperature and the temperature at the cathode. With a cathode at the center of a bath in a circular anode container, the proper conditions are not so easily maintained without it becoming *"necessary for one person to devote all his attention to the raising of the cathode,"* and to prevent the irregular growth of the calcium rod and short circuits. Therein lies an advantage in the shape of apparatus No. 3 and the iron ribbon contrivance, which can easily be raised regularly by mechanical means.

The "thin ribbon" of calcium to which Mr. Frary refers was usually about ½ inch (1.25 cm.) thick (see photograph).

As for the explanation which Mr. Frary would have me give on why accurate results for current density cannot be obtained under the conditions that prevail when a calcium rod dips into fused calcium chloride, I reply that the total area entered by the current is indefinite and changing continually, and other cathode conditions are changing when, as one may infer from

Mr. Frary's own description, the deposit is now a "sponge" (solid or semi-solid or what?), now a molten globule slipping about under the cathode, and now a mass suddenly cooled on to the main calcium rod—and all this under the surface of an opaque liquid! Since current density has a very determining influence upon the prevailing temperature at the cathode (the very surface where the metal comes out nascent) and the physical nature of the calcium deposit, it is highly necessary to get and maintain more definite conditions than are ordinarily met in working the Rathenau principle.

The black particles of which I write several times in the paper, and upon which I look as being finely divided calcium, *did not evolve acetylene when treated with dilute acid. Hydrogen was the product, beyond a doubt.* The writer is fairly familiar with the properties of these gases and tests for them. I should like to call the attention of Mr. Frary to the admirable work done by Richard Lorenz on "The Electrolysis of Fused Salts."*

Regarding the decomposition voltage of calcium chloride, as discussed by Mr. Frary in the last paragraph of his criticism, I must call Mr. Frary's attention to the fact that when copper is used as the cathode 3.2 is the decomposition voltage according to Willner, *but when iron is the cathode, 2.6 to 2.8 is the value, and not 3.2.* The decomposition voltage means but little until we know the actual working conditions under which the value was obtained.

* Trans. Am. Electrochem. Soc. 6, 160 (1904).

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ELECTROCHEMISTRY OF POLONIUM AND OTHER RADIOACTIVE ELEMENTS

PRELIMINARY PAPER

By A. R. Johnson.

In the early part of the present year I had occasion to make an analysis of pitchblende. The main object of the analysis was the separation of the radioactive constituents. Polonium is one of the radioactive elements present, and it was to this very interesting element that my attention was soon drawn more closely than to the others.

As is well known, polonium is precipitated by, *or with,* the sulphides of bismuth, copper, iron and lead, but especially with bismuth. This fact was made use of in my work, and the separation carried out according to the general directions of Boltwood and Marckwald, *i. e.,* precipitating bismuth as sulphide from the active solution, redissolving the sulphide in HCl and again precipitating the bismuth (with the polonium) as oxychloride. In order to separate the polonium from the bismuth, the oxychloride was just dissolved in HCl and then a copper disc rotated in the solution. The polonium deposits on the copper disc, rendering it radioactive. To the electrochemist this last step is interesting and suggestive.

We know that if we dip a strip of iron in a copper-sulphate solution, the iron becomes coated with copper, and sulphate of iron goes into solution. Likewise, if zinc is placed in an iron solution, the iron is deposited, and the zinc goes into solution. We say, in electrochemistry, that one metal replaces another if it is more electropositive (has a higher single potential)—thus, iron is more electropositive than copper, and zinc more than copper or iron. As polonium can be obtained by dipping strips of copper or bismuth into its solutions, we may feel fairly certain

that polonium is a metal, and that it is less electropositive than copper or bismuth. Now, if we had a compound of a metal whose single potential we could not measure by our common apparatus used for this purpose, but which could be precipitated by other metals, then by dipping strips of various metals of known single potentials into the solution and noting which precipitated the element and which did not, we could assign to the element a place in the electrochemical series, and thus fix fairly narrow limits within which the single potential of the metal must lie. Data thus obtained for polonium indicate that its single potential is very probably about —0.8 volt (calomel electrode standard), for it is precipitated by copper, but not by mercury. When the copper strip is amalgamated, there is a slight deposition of polonium, but this would be expected from the composition of the amalgam. As one passes up the series to metals of higher and higher single potentials, precipitation does not necessarily occur all the more readily, for while bismuth precipitates polonium readily, lead or iron or zinc appear to act rather indifferently. At this time I have not sufficient experimental results to warrant a plausible explanation.

It next occurred to me to attempt to electroplate polonium out of solution, just as one would copper, for instance. Two polished inactive copper plates of equal area were connected to the terminals of a storage cell, which was in series with a 20-ohm resistance box, and both plates were simultaneously submerged in a solution containing a known quantity of polonium (previously determined by the electroscope). On allowing a slight current to pass an hour or more and then measuring the activity of the anode and cathode by the rate of discharge of an electroscope, it was found that practically all, *though not entirely all,* the polonium was deposited on the cathode, *thus showing that polonium moves with the current in solution, as do real metals.*

Another variation of the experiment was carried out, in which an inactive cathode of copper and an active anode of copper were connected to the terminals of a battery and submerged in a slightly acidulated water electrolyte. Here also the cathode soon became the active plate under the influence of the electric current. But the new cathode never became as active as the anode had been, and it was concluded that, since copper was also deposited, some

of the polonium was buried in the copper and its activity absorbed. In order to test this last assumption and also get fairly pure deposits of polonium, the following experiments were performed: An active anode was prepared by plating an exceedingly thin film of copper on a sheet of platinum and then rotating in a polonium-bearing solution until rendered active. A platinum cathode was used. With a current of a few milli-amperes, the slight film of copper would disappear from the active anode and appear on the cathode in a very few minutes, but the polonium required as many hours to pass to the cathode. Thus, by making use of this time factor, was shown the possibility of separating polonium from the copper and depositing it, *or leaving it deposited,* on a metal surface of a different character, and also the fact that the polonium can be transferred from one electrode to the other without considerable loss.

The great and all-important law of electrochemistry is that of Faraday, and I believe I am justified in indulging in a little speculation as to the meaning of the above-mentioned experimental facts, qualitative though they largely are, when viewed in the light of this law. If polonium exists in solution like any other metal, how is it that it requires such a relatively enormous number of coulombs to deposit such an infinitesimal quantity of it? Even the most active deposits of polonium ever prepared were not weighable. Though deposits of polonium have been obtained by Madame Curie as active as an equal surface of radium, still the deposits were practically imponderable. Nor do we know of any compounds of polonium as we do of radium; hence we know nothing of the valence of the element. If the meager experimental facts thus far obtained are reliable, we must infer that either the atomic weight of polonium is exceedingly small, or its valence very great, and hence a series of reductions must be probably made before the element will deposit electrolytically. The former view seems by far the more plausible.

In my work, deposits of polonium from 2 to 12 times the activity of an equal area of uranium oxide were used. In the case of deposits obtained by rotating a copper disc in the active solution, the activity increased fairly rapidly at first, then slowly approached a limiting value. When deposited electrolytically, however, the activity increased at the cathode fairly proportion-

ately to the time, but apparently quite out of proportion to the *amperage*.

In conclusion, it appears to me that some well-devised and carried-out quantitative experiments would prove of considerable value in determining the nature of polonium, as well as adding new ideas to the electrochemistry of this element.

Regarding the work done by others in the electrochemistry of radioactive elements, attention may be called, first of all, to that of our fellow-member, Dr. Edgar F. Smith,[1] of the University of Pennsylvania, on radium. By the use of his ingenious mercury cell, he has found that radium can be determined much in the same way as barium.

In 1903 a good paper appeared, by Von Lerch,[2] having to do entirely with the deposition of thorium products from solutions. In the same year papers appeared on the same subject by Miss Brooks[3] and Miss Gates,[4] both students of Rutherford, and in 1905, another of his students, Miss Slater,[5] published a paper also on the electrolytic separation of thorium products.

It is known that thorium products may be deposited under the influence of a strong electric field in air, and in this work of Rutherford's students the same idea seems to have been kept in mind.

Rutherford, in the last edition of his "Radioactive Transformations," expresses the fact that much of value would result from a study of the electrochemistry of the radioactive elements.

DISCUSSION.

Dr. H. Schlundt: I would like to ask how long Mr. Johnson continued his experiments?

Mr. Johnson: Usually two or three hours; most of the experiments, I would say, two hours.

Dr. Schlundt: The entire polonium was not deposited in that time, was it?

[1] These Transactions, **16**, 75 (1909).
[2] Von Lerch—Annal. d. Phys., Nov., 1903.
[3] Miss Brooks—Phys. Mag., Sept., 1903.
[4] Miss Gates—Phys. Rev., 1903, p. 304.
[5] Miss Slater—Phil. Mag., May, 1905.

MR. JOHNSON: Not all, I never succeeded in getting out the last trace of polonium.

MR. SCHLUNDT: A student working in our laboratory conducted some experiments with a view of making this work quantitative, and we used bismuth buttons instead of copper discs and found it necessary to rotate those buttons for several days to secure complete deposition of the polonium.

MR. JOHNSON: I have also used bismuth. It will take several days to throw down the polonium if you use buttons of bismuth, so I took one of those buttons and ground it up to a fine powder, increasing the surface enormously. I simply threw it into the solution and thus by simple deposition took out the polonium. Another way, not mentioned in my paper, was to take a strip of platinum and coat it over with bismuth. I noticed in grinding bismuth in an agate mortar that the pestle was coated over with a fine film of the metal, so I made use of that fact in getting a thin film of bismuth on platinum. The bismuth seems to be of a sort of vitreous nature and you can rub it or grease it right onto a piece of metal.

DR. L. KAHLENBERG: It is very interesting to notice the speculation which Mr. Johnson brought forth in connection with the valency of polonium or its possible electrochemical equivalent. Of course, in order to make any deductions as to either its valency or its electrochemical equivalent it would be necessary to make absolutely sure there is no other material deposited during electrolysis of this polonium. I should like to know whether Mr. Johnson assured himself of the fact that there was no other material deposited but polonium.

MR. JOHNSON: I think in most cases there was something deposited. You notice I worked with at least a little copper or a little bismuth and it would be very hard to get a sufficiently small current so that nothing else would come out. The current would not devote its entire time and attention to the polonium.

DR. KAHLENBERG: That is of course true, but we need to know what other substances and just how much of them are deposited. If we know that, we can deduce the electrochemical equivalent of polonium, but as long as we know neither the exact

nature of the other products nor their amount, it is futile to speculate as to the electrochemical equivalent of the polonium.

Dr. J. W. Richards: I would like to ask if Professor Johnson has any idea as to the amount of polonium in the solution.

Mr. Johnson: As I stated in my paper, perhaps the total amount of polonium obtained by all of its devotees in the world would not turn a balance, and yet as measured by the electroscope it is exceedingly active, much more active than an equal area of radium, so there certainly is a field for speculation.

Dr. Richards: Then, Mr. Chairman, I would ascribe the fact of the small amount of the deposit to the dilution of the solution. We all know that if you use a very dilute solution, for instance gold-cyanide solution, you get a very small ampere efficiency on the current passing. I have experimented with dilute gold-cyanide solutions and have never been able to get more than about one-half of one percent current efficiency. The amount deposited by the current is limited by the amount which can get to the cathode to be there deposited, and my own personal view is that since by diffusion only an infinitesimal amount can get there to be deposited, therefore, the amount of deposit bears no relation to the amount of current used.

Dr. Schlundt: Professor Richards' question can be answered if Professor Johnson will state what amounts of pitchblende he used in his experiments. Since one gram of high-grade pitchblende would not contain more than 3×10^{-7} grm. radium and the polonium would be about 1/10,000 of that, you can get an estimate of what the quantity of material here is that we are dealing with.

A paper read at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, Ill., October 14, 1910, President W. H. Walker in the Chair.

THE PRESENT STATUS OF OZONE WITH REFERENCE TO AIR PURIFICATION.

By Ralph D. Small.

Fremy, one of the world's noted scientists, said: "There is no discovery in modern chemistry more important than ozone."

The development of ozone for industrial uses, water purification and ventilation has progressed rapidly since 1903, which seems to be the median line between inaccuracy and accuracy, so far as determination, concentration, economical operation, properties and uses of ozone are concerned. In 1890, for instance, the French Academy appointed a commission to report on the status of ozone in Europe. After a lengthy investigation, their report submitted proved absolutely inconclusive. The members were almost divided as to what they recognized had been scientifically proven.

From 1895 to the present date the whole subject has been largely taken out of the laboratory and put on a commercial plane, and this has been chiefly dependent upon the progress and developments that have taken place in the electrical industry.

Ozone, as every chemist and physicist is aware, is merely an allotropic modification of oxygen, and its symbol in chemistry is O_3. You frequently see the formula $3O_2 = 2O_3$. This is an imperfect presentation of the relationship of oxygen and ozone. When 3 molecules of 2 atoms each of oxygen are split up by an electrical stress, the free atoms recombine into 2 molecules of 3 atoms each, but the energy required to bring about the chemical change is the most significant part of the equation, so that modern chemistry states it thus, $3O_2 + \text{energy} = 2O_3$.

As this paper is to be largely devoted to the uses of ozonized air as an adjunct or supplement to ventilation, very little reference will be made to the largest commercial use to which ozone has at present been put, namely, that of water purification, except by way

of general information to state that water purification by ozone has in many places in Europe supplanted every other method of filtration and sterilization that is known. In the United States, owing probably to imperfectly developed methods, a like success cannot be claimed.

Schneller, De Fries, W. Siemens, Vosmaer, Becquerel, Otto, Ehrlwein, Gerard, Berthelot, Koch and Ohlmuller have all been largely responsible for the progress that has been made along this line. Today there are over 40 cities and towns in France that are purifying all or part of their water supply with ozone apparatus. In Germany also this method is being rapidly adopted.

Some idea may be gained of the efficiency of this method when, as is stated in the *Engineering News* of April 28th, on page 497, "Ozone treatment reduced the bacterial count in water from 12,000,000 to 40 with a total consumption of 18 grams of ozone per cubic meter."

Today there are over 150 patents on ozone in the United States Patent Office, and this department is rapidly becoming one of the "busy" departments, thus indicating the amount of interest that is now being taken in the latest development of the electrical field, or, more properly, the electrochemical field.

One of the former heads of the Westinghouse interests has been credited with the remark that "Not only was ozone the coming thing in electricity, but was destined to be, in the course of time, one of the largest fields with which electricity would be identified, barring its use for light and power."

There are various ways of producing ozone, such as the oxidation of phosphorus, or the action of ultra-violet rays upon air, these rays being produced by a mercury vapor lamp in a quartz receptacle; or by heat, according to Nernst and Clement, by which they produced 3 grams per kilowatt hour. It should be stated here that concentration is the percentage of ozone, usually measured in grams, contained in a cubic meter (about 35 cubic feet) of air. All these processes, however, are not economical for commercial purposes. Ozone is produced in nature by evaporating water, when acted upon by the ultra-violet rays of either sunlight or electrical discharge. It is also produced from green plant life in what is known as the process of photo-synthesis.

In this process carbon dioxide is absorbed and unites with water to form carbo-hydrates. In this chemical reaction the atoms of oxygen are liberated and appear in a nascent state. This affords a logical origin for the presence of ozone in the vicinity of forests or where much plant life is found. Its presence in mountainous regions and higher air strata is largely accounted for, first, by the lack of organic impurities to use it up, and, second, because the sun's ultra-violet rays, having less atmosphere to pass through, are more slowly absorbed. This is investigated quite extensively by Ladenburg and Lehmann, as was noticed in the *Scientific American* of August 6th, and their works are now the basis of a series of investigations on the part of the United States Weather Bureau. The spectroscope is used to determine the presence of ozone in such investigations.

It is generally conceded now, since the research of Henriet and Bouysey, and also Steinmetz, that ozone is created by the action of ultra-violet rays upon oxygen; that it is an endo-thermic process; heat is absorbed. In nature this usually takes place, and is more observable when there is much electricity in the air, or when water evaporates quickly, as on the beach of the sea-shore, where it is in a finely divided state and on account of which these rays have a better opportunity for their peculiar action.

For air purification purposes, ozone is now being made with generators, which first change the direct current to an alternating current, preferably with cycles not less than 60, and then step-up the voltage to all the way from 5,000 to 30,000, although it is now thought that to obtain the best economies, a voltage under 8,000 is poor practice. The discharge is made by electrodes on either side of a dielectric, such as glass, micanite, mica or some high insulating material, there being an air gap between the dielectric and the electrodes. The electric glow, which has no sparks such as are exhibited in the voltaic arc, and which is comparatively heatless, is a brush discharge, purple in color and fairly quiet in its action. Various types of condensers and electrodes have been used from 1859 down to date. The consensus of modern opinion is that point electrodes, such as employed by Andreoli and others, have disadvantages, first, because they quickly lose their pointed character and round off,

or, second, because a minute particle of dust can do a great amount of destructive work on a small point in generating heat and interrupting the flow of electricity; third, because the necessary cleaning of an infinitely large number of points requires too much attention. Leon Gerard, one of the leading electrical engineers of Belgium, states: "The aigrette or point electrodes apparatus has only 55 percent efficiency of those where the glow discharge is used." Other types of electrodes are either plates or cylinders on either side of a dielectric material, and these appear in various forms—flat, serrated, gridded or perforated. Another type is the covered electrode, with no metal exposed, which is very commendable. A fourth is the use of a rotating fan electrode, such as is shown in the Vohr type, which has the advantage of quickly forcing the air through the generating field and ozonizing it at the same time, thus giving a high purity of product. It is generally regarded as axiomatic that the briefer the period of ozonization, the purer the resultant gas, purity meaning practically an absence of oxides of nitrogen, which are principally produced by heat, sparking or the presence of dirt.

The amount of nitrous oxide generated by any properly made type of air ozonizer, however, is so infinitely small that it can be totally disregarded. This statement, however, does not apply to all ozonizers, as will be later explained. It may be stated that the more modern machines consume in operation 40 to 250 watts per hour.

Normal air has as its constituents, according to recent tables, giving volumes per 1,000 and not using the decimals beyond the 4th place:

Nitrogen	769
Oxygen	206
Aqueous Vapor	14
Argon	9
Carbon Dioxide	0.33
Hydrogen	0.19
Ammonia	0.008
Ozone	0.0015
Nitric Acid	0.0005

This is for normal air. It does not apply to air where all the ozone has been used up in oxidizing such various substances as the exhalations and emanations from millions of human beings, horses, automobiles; smoke from factories, trains, boats; gases

and dust from manufacturing processes; volatile substances from rendering plants, packing houses and decomposing garbage and refuse in the street.

Authorities differ as to the amount of ozone in the air. It has been given all the way from one part in 1,000,000 by volume up to one part in 20,000,000. Perhaps a figure from one in 1,000,000 to one in 5,000,000 would represent what most have agreed upon as correct for those places where the presence of ozone is easily detected. So that the best constructed ozonizers of later years have been in alignment with, or very little in excess of, the concentration which nature provides in localities remarkable for their invigorating air. German scientists have stated: "1/10 of a milligram to 1 milligram is the ideal concentration for continuous breathing." The limits as recommended by recent investigators are somewhere between 1/10 of a milligram and 2 milligrams. If a density of much over a centigram is used, another factor must be relied upon to dilute the ozone to a point where it is agreeable to breathe, that is, the rest of the air in the room. This is unscientific, because you are dealing with a factor outside of your own control, and the air currents of any room differ from those of every other. The machine that delivers the ozone with a continuous uniform concentration and with a controllable yield is built along sane, scientific lines.

Properties of Ozone.

Ozone can be condensed to a liquid state of a bluish color, with a specific gravity of 1.46. In this state it boils at about 120° C. Its density is 1.5 as compared with oxygen, and 1.66 as compared to ordinary atmosphere. It is slightly soluble in water and more soluble in certain oils. It reverts to oxygen at 270° C. It is unstable, and rapidly disintegrates on standing. The loosely attached third atom is constantly tending to fly off and combine with other atoms, as it has a remarkable affinity for all carbon or compounds of carbon, which, so far as ventilation is concerned, will be hereafter referred to as organic matter.

Its value as an oxidizing agent is due to ease of application and because nothing but oxygen is used in reaction. In the lighter concentrations its odor faintly resembles that of freshly bleached linen, and is crisp, refreshing and exhilarating. It can

be detected by the nose when present in one part to 10,000,000 of air. In the higher concentrations its odor is pungent, heavy and disagreeable. Many of the properties of ozone are discussed in the works of Pescheux, Gerard, Le Coux, Warburg, Mendeleef, Berthelot, Ehrlwein and Dr. Fischer, of Germany.

Heat and humidity are unfavorable conditions for the generation of ozone.[1] For this reason different methods have been employed to keep the electrodes cool. Steynis uses ammonia gas in pipes; Gerard uses oil. Others employ water jackets. The preferable method for air purification is the rapid passage of air by suction pumps or fans, such as are found in the Siemens & Halske later models in Germany and the Vohr model in the United States.

Any type of ozonizer where no mechanical means are provided for forcing the air rapidly past the electrode surface is utterly unreliable. In the first place, the air will remain for too long a period in the heat zone and thus produce an unsafe amount of nitrous oxide. Furthermore, this type of generator is unscientific, as there is no means of obtaining either concentration or yield, since there is no regular air flow to measure by. You must guess at what is being made and how much of it.

The amount of ozone generated is in direct proportion to the wattage of discharge per unit of air ozonized. Some element of heat is present in the so-called "cold" discharge, and this tends to destroy a portion of the ozone generated and also destroys the theoretical accuracy of the above statement. Heat increases as the square of the current of discharge. It is therefore desirable to use a high voltage and low amperage, and it has been found that from 8,000 to 12,000 volts produce ozone with commendable economy.

Very high concentrations are needed for such purposes as water purification, the bleaching of fabrics, the destroying of disease germs, treating of petroleum oils, cyaniding (where with ozone it is now possible to get 94 percent efficiency off the plates, where in many instances only 60 percent was obtainable before), sterilizing infected rooms, ships, etc. For all of the above from 1 up to 12 grams are required. As high as 30 grams concentration has been obtained. High concentrations necessitate high

[1] See L. Gerard's Treatise in the August, 1909, number of Society of Belgian Electricians.

wattage of electrical discharge per unit of air. Here the air passage must be slow, which, of course, results in low volume of ozonized air. The converse, of course, holds true, that the more rapid the air flow, the higher will be the volume of ozonized air, but the lower the density or concentration.

For all these large concentrations it is better to dry the air by the use of quick-lime or other means, but for ventilating purposes it is not necessary to resort to this in the more recent types of ozonizers. One of the objections to extraordinary humidity is that a small amount of peroxide of hydrogen is liable to be formed.

Method of Measuring Ozone.

The determination of the quantity of ozone generated is frequently obtained by using iodide of potassium solution. The iodine is freed by ozone, is acidified, then titrated by sodium thiosulphate and starch.

Air Purification.

Of all known subjects which are intimately connected with our health and working efficiency, the least understood, the least attended to, with the most widely varying opinions in regard to it, is the subject of air purification and the chemistry of the air we breathe. Twenty years ago we would have complacently taken any kind of water from any spigot or hydrant without much thought. Today we won't take that chance because we know it is a chance that may produce harm. We now have spring water in bottles in our offices, or we use boiled or filtered water at home. Twenty years ago we took any kind of food in tin cans that was handed us at the grocery store, but today the laws of the United States protect us. Pure food laws have materially cut down the ptomaine poisoning, dysentery and various complaints arising from diseased or adulterated food. At present, however, although we eat but three times a day and drink water seven or eight times, we are breathing continuously both night and day and are thoughtlessly taking into our system any kind of air that we happen to find.

What is the harmful part of bad air? The consensus of modern chemists, physicists and scientists on this subject is abso-

lutely conclusive; it permits of no debate. Experiments have been tried, tests have been made, and the old bugaboo—carbon dioxide—has been effectually exposed. Many persons used to entertain an idea which is rapidly becoming obsolete, that is, that the carbon dioxide in the air is the particular thing that creates the harm. Carbon dioxide is harmful *only* in that it *reduces the oxygen* supply by displacing it. As long as you can get the proper percentage of oxygen in the air that you breathe, the amount of carbon dioxide produced in any chemical laboratory can be present, according to the best scientists of the last ten years, to an amount of 20 times that which many engineers put as a figure destructive to life. Carbon dioxide is not poisonous, but when present in quantities in any air it is a danger sign that impurities exist in that air. But remember that it is a *sign board,* and not the danger itself. It is the organic impurities exhaled at the same time as the carbon dioxide that are poisonous, so merely getting rid of carbon dioxide is a good deal like burning up the danger sign to get rid of the danger.

Ira Remsen, one of the leading chemists of the United States, president of the Johns Hopkins University, of Baltimore, has done much to explode this carbon dioxide theory. He states: "Carbon dioxide is given off from the lungs just as it is from the fire. It is a waste product; it is not poisonous any more than water is. If, however, pure carbon dioxide is introduced into air, it has been found that as much as 5 percent may be present without serious results to those who breathe it.[2] The ill effects of breathing the air of a badly ventilated room occupied by a number of human beings appear to be due for the most part to the presence of the small quantities of decomposing organic matters which are given off with the carbon dioxide and other gases. These act as poisons."

In "Air and Life," by Henry de Varigny, M.D., Sc.D., member of the Societe de Biologie and demonstrator of Museum of Natural History of Paris: "The atmosphere of a room may be considered vitiated as soon as it begins to smell close. This is not due to carbonic acid, which is scentless, but to organic impurities from the skin, mouth, etc."

* Five percent is 500 parts in 10,000, though 20 parts in 10,000 is claimed by some as a menace to life.

Prof. S. H. Woodbridge, in Connecticut School Document No. 13, 1908: "The most active and dangerous impurity in the air of occupied enclosures is the matter of organic nature, thrown off by the body through its pores. That matter rapidly changes in character, passing through a fermenting and decomposing to a putrescent condition. The longer it is retained within a room, the worse its odor becomes and the more morbific its condition."

The Engineering Magazine of August, 1910, page 698, exhaustive article on "Air Conditioning in Factories," P. R. Moses, which reviews broadly the whole practice of ventilation and the methods employed: "Carbonic acid gas itself is not dangerous in the quantities in which it is found; it might be present to 10 times the amount usually allowed in good practice before it would become actually dangerous."

Organic impurities come from a variety of sources, as has been previously mentioned. In all confined spaces, however, the chief source of air pollution is the organic matter cast off through the pores of the skin and the nose, throat and mouths of the individuals occupying that space. The longer that matter which the body has cast off remains suspended in the air, the quicker it deteriorates. When it reaches a putrescent state, it is unfit to be rebreathed. This is air sewage, and is just as unfit to take into the system as diseased meat would be unfit for the stomach. What our body has cast off it is safe to assume is unfit for further use. This organic impurity has recently been called "crowd poison," according to Dr. Fischer, in "Ozone and Air Purification."

He states: "What is known as 'crowd poison' is responsible for many of the bad air diseases. A large amount of decomposition is continually going on upon the surface of the body and in the nose, mouth and throat of every individual, so that large quantities of these 'decomposing products' are thrown out into the air. As these substances are formed more rapidly when there are a number of persons confined to the same space, they have been called 'crowd poisons.' Wherever there is decay, there is bound to be odor, and the unpleasant smell in confined spaces is due to this 'crowd poison.'

"'Crowd poison,' because of its odor, also produces *shallow respiration* with the decreased oxygen supply which this occasions.

It also has an effect upon the cell tissues in retarding proper oxidation. When the body cells are not properly oxidized or do not properly take the oxygen from the haemoglobin (which is that part of the blood which carries the oxygen to the tissues), we have more than enough of this haemoglobin.

"It is a general law of nature that what cannot be used is destroyed, so that we soon have a reduction in haemoglobin, and *anaemia* results. With the progress of anaemia, other disturbances manifest themselves. Without sufficient oxidation, the fires of life begin to smolder. Food is not properly digested or assimilated. Malnutrition ensues, and the weakened body easily falls a prey to any disease.

"*Prevention is better than cure,* and ozone, by destroying air poisons, does prevent the diseases which follow upon bad air.

"Just as diphtheria antitoxin injected into the body will prevent diphtheria, so is ozone undoubtedly the most efficient agent for preventing diseases resulting from bad air."

So that it would seem that, while ventilation is necessary to bring in out-of door air to replace the oxygen which our breathing uses up, outdoor air alone is absolutely insufficient to purify the indoor air. It never did and never will *destroy* the impurities that constitute the danger element. Nature purifies her atmosphere with ozone. Man can purify it only with ozone. In "Atmosphere in Relation to Human Life and Health," F. R. Russell, member of the Royal Institute of Great Britain and fellow of the Sanitary Institute, says: "Ozone is an important constituent of the atmosphere, greatly contributing to its purity and freshness and to the vigor of human life. Its activity is so great and its function so beneficial that its presence in normal quantities is a fair guarantee of the purity of the air and of health conditions. No ozone is found in the streets of large towns, and in most inhabited rooms, near decomposing matter, and in confined spaces generally."

Nothing has been said about ozone as a deodorizer. Its properties are remarkable in this line, and with higher concentrations, almost any odor known—excepting the extraordinary perfumery from the pole-cat—can be successfully combatted. In an office, factory or home the chief odors to be eliminated come from tobacco smoke, cooking, laundry, sick-rooms or any overcrowded spaces.

Therapeutics.

It now seems to be regarded as an accepted opinion that colds and kindred diseases come from bad air, chiefly because bad air disturbs that part of the nervous system which regulates the blood circulation, and local blood congestion ensues, bringing with it an interference with certain bodily functions which destroy the bacteria constantly taken into the system. Thus infection occurs, lowering resistance to disease, and we start with colds, which are frequently the forerunners of tonsilitis, bronchitis, pneumonia, and even tuberculosis. Sir Frederick Treves, one of the four leading physicians of Europe, recently stated: "The idea that colds are caused by drafts is absurd. No cold ever had such an origin. Colds are a result not of drafts, but of stuffy rooms."

Undoubtedly ozonized air acts as a preventative of conditions which bring about many of our colds, and it is on the preventative rather than on the curative side that it has a serious claim to your consideraion. There is just as much and no more magic in ozone for continuous breathing purposes as there is in pure air. Pure air will help the body to cure itself, and that is all that ozonized air in a concentration proper for breathing will do. There are so-called "doctors' machines," from which the patient is supposed to inhale ozone passed through turpentine oils for a few minutes each day. Nothing will be said about such apparatus except that it stands to reason that you cannot be sent to the Adirondacks, or Martha's Vineyard, or the Rocky Mountains and breathe the air there for half an hour, and then be sent back home with any reasonable expectation that the half hour's treatment will materially change your state of health. Interrupted administrations of ozone in high concentrations certainly cannot be seriously considered as beneficial as its continued use in more diluted and diffused form.

Dr. Oscar Linder said, in a paper read at the convention of American Institute of Chemical Engineers, June 24, 1910:

"It is well known that this matter, which we have defined as air sewage, is a specially attractive ground for bacteria, miasmata and other animal and plant life of the lowest order, which thrive in cities and congested districts. In such small concentrations as

ozone is employed in ventilating, the destruction of this air sewage is probably its beneficial action rather than the direct destruction of bacteria, which has sometimes been accredited to it. It has been proven that ozone, when diluted to the extent of 1 part in 1,000,000 parts of air, cannot act directly as a bactericide, but it is an established fact that even in such dilutions it acts as a deodorizer and destroyer of the food and favorite surroundings of the bacteria, thus depriving them of the conditions favorable to their propagation."

This is confirmed by D. Mendeleef, the noted Russian chemist, in his "Principles of Chemistry, 1905," when he says: "The air of dwellings contains no ozone—the air of fields and forests always contains ozone; that miasmata, etc., are destroyed by ozonizing the atmosphere."

Abroad, ozone as an air purifying agent and as a supplement to ventilation has been extensively used in factories, theaters, mines, ships, schools, hospitals, hotels, restaurants, gymnasia, offices, cold-storage houses, libraries and homes.

The use of ozone in the purification of air is undoubtedly one of the most valuable of the newer achievements of electrochemistry, first, as a preventative of conditions which undermine health; second, as a promoter of working efficiency, which involves the third—an increaser of business output, so that commercial and physical welfare are materially aided by a little boxed-up lightning placed in one's office, factory or home.

The air we breathe is more important than any other one thing in the world. Health, vigor and pleasure of living depend upon it. It's the first thing we get in the world, the last thing we give up, and is necessary to us every minute of the intervening time.

BIBLIOGRAPHY

Angstrom—Arkiv for Matematik, Astronomi och Fysik 1904—p. 395.
Landenburg & Lehmann, Annalen der Physik Vol. 21, 1906—p. 305.
Berthelot.
Ramsay.
Faraday.
Becquerel.
Bunsen.
Koch.
Pasteur.
Warburg and Leithauser, 1906.
Fischer and Marx, Ber. d. Deutsch. Chem. Ges. 1907.

Trillat, Les corps gras industriels, 1900.
Will, 1908.
Sigmund, Centralblatt, B. and P., 1905.
Pecheux, 1906.
Tait.
H. de Varigny.
Ehrlwein.
W. Siemens.
Prokauer.
Ransome.
Dyott.
Linder.
De la Rive.
Marignac.
D. Mendeleef.
Bouyssey and Henriet.
Ohlmuller.
Froelich.
Bull: Pasteur Inst., 1906.
Soulier "L'industrie electrique," 1910.

DISCUSSION.

Mr. Carl Hering: There has been some discussion elsewhere as to how ozone kills the bacteria. It seems that Mr. Small takes the stand that it does not kill the bacteria directly but merely starves them to death by destroying that on which they live. Others have claimed it completely destroys them by oxidation, that is, by complete combustion, as though they were burned up; and still others claim that it simply kills them but does not destroy them. In connection with the last theory someone remarked that to drink water in which bacteria had been killed by ozone would be like swallowing a graveyard.

Mr. R. D. Small: I think you misunderstood. In higher concentrations of from four or five grams to twelve, ozone will kill any form of bacterial life, but in these concentrations ozonized air is absolutely unsafe for continuous breathing.

The concentrations approved by German and French authorities, who have given the matter exhaustive study and experimentation, is a fraction of a milligram.

Mr. Small (*Communicated*): Owing to the fact that I could only hear a portion of Mr. Hering's remarks I did not answer a part of his statement.

It is true that even in concentrations of a milligram and under, ozonized air will destroy the organic impurities suspended in the atmosphere of all indoor space. This destruction is by oxidation or complete combustion and the resultant is in a volatilized form. Even if the suggestion which he quoted was correct, that the bacteria were only killed, it would still be preferable to have a dead germ in the system rather than a live one.

In connection with the destruction of bacterial life, recent demonstrations in France and Germany have tended to establish the fact that after ozone has acted upon the bacteria in water the combustion has been so complete that there is no residuum and that hence the solid matter has been converted into a gas and released at the surface of the water.

A paper read by J. W. Richards, at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, Ill., October 15, 1910, President W. H. Walker in the Chair.

ELECTRIC SMELTING FURNACES AND THEIR APPLICATIONS

By Marcus Ruthenburg.

Electric smelting has emerged from the realm of mere scientific investigation, and has taken a firm foothold in the commercial production of metallurgical and other products, which can be produced either more cheaply, or of greater purity from base starting products, than by other means; or in some cases they do work or make products that cannot be done or produced in any other way.

Of furnaces there are many. Their claims to radical superiority, one over the other, except in mechanical detail, may be at once dismissed as existing only in the minds of the inventors and those interested in exploiting them.

The first practical furnace operating under modern conditions was that of Siemens, and all the details of current regulation necessary in an arc furnace, typical of some modern examples, are clearly shown in Siemens' furnace of thirty-five years ago.

It has been well said that "the time has arrived at which the furnace man and the metallurgist should take a hand in the development of the electric furnace." This being so, along what lines should that development be?

Whether the furnace be used for refining steel, smelting pig iron, smelting copper ore, smelting complex ores of lead and zinc, smelting zinc, smelting nickel-cobalt arsenides, smelting nickeliferous pyrrhotite, smelting tin ore and tin slags, making alloys of manganese, chrome, titanium, vanadium or silicon, the furnace does not depart from being a mere receptacle or container for holding the raw material to be operated on—the molten product—and means for minimizing the radiation of the electrically produced heat.

True, it may differ in form, in lining, in the means of introducing raw material, the means for removal of products, and

means and facility of repair—all of which are of vital importance.

The kind of current used, and the means of applying it, are also important. Direct current, on account of commutator troubles, is not used, except for electrolytic work, and the furnaces for such work are of the very simplest description.

Single and multi-phase currents are most extensively used, the advantage for electrical and heat distribution being with the three-phase current.

Constant voltage is almost universally used, simply because lighting and power supply demand such regulation, and the smelting supply is taken from the same source, or from a generator that has been designed on the same lines. The latest and best work is done with constant current with automatically regulated non-arcing voltage, using a slag as resistor, the electrodes functioning merely as conductors to deliver the current to the slag.

The electrodes are usually held by heavy clamps, to which are also attached the flexible leads for supplying them with current. When in the course of use the clamps reach the roof of the furnace, the electrodes can be fed no further and must be replaced by new ones.

The heaviest consumption of electrode is not at the end, and useful; but along the body, and useless. Water jackets around the electrodes remedy this wasteful consumption of carbon. It is quite safe to carry them clean down to the slag, and though the current notion may be to speculate on what will happen if a jacket be cut, I can from long experience say, absolutely nothing will happen other than chilling your furnace.

I have seen water pour into the furnace until it was black; I have run the hearth out, broken the slag with a sledge, and poured a bath of steel clean.

With a removable hearth, which may be tilted, a ladle is done away with, and no skulls are made.

The hearth is accessible in all parts for repair, and may be replaced in a few minutes with a spare one. For experimental work, hearths with acid, basic or other lining, may be kept ready, and used in the same furnace at a few minutes notice, for the change.

Other important points in an electric furance supplied with

alternating current are to minimize joints and contacts; have no heavy solid conductors, but split them up. When joints are unavoidable, see that contact is good and of ample area. Conductors should be ample for maximum current, —err, if at all, in making them over what is needed. They are bought but once, and their scrap value is high.

To enumerate in detail the uses that electric smelting furnaces may profitably be put to would embrace far more than I contemplate; further, in not referring to graphite and carborundum furnaces, it is not that they are unimportant, but that they are not smelting furnaces.

The smelting of iron ore electrically is an accomplished fact, and if the same principles that apply to the selection of a proper site for a blast furnace are used, the electrical proposition stands or falls in the same way. Either case resolves itself largely into one of transportation, the items being ore, fuel (power) flux and finished product.

That furnace which can gather fuel, flux and ore, and deliver finished product to market with the least *mile tons,* other things being equal, wins.

Therefore, every proposition must be worked out on its own basis. Power in Norway may be dear at *any* price if raw material and finished product must be freighted in and out, unless electric current is the chief item of expense, and the product cannot be made otherwise.

Copper ores, both carbonate and sulphide, are shipped half around the globe, when, after paying freight, but a small portion of their value remains to pay for the mining and profit. Water power or coal, and in some cases, both, occur in close proximity to the mines; instead of shipping a 20 percent to 40 percent ore, it should be smelted at the mine to finished anode metal, making much better recoveries than a blast furnace, and doing it more cheaply. In a recent case, the difference in slags made in the electric furnace and the blast furnace amounted to $1.00 a ton on 100 tons a day—making a saving of $35,000 a year.

In smelting nickel-cobalt arsenides, great trouble is experienced in roasting, and if not roasted, an inordinate amount of speiss is made. Electrically smelted, without roasting, the last traces of arsenic are removed, no speiss is formed, and clean slags are

made. A second melt delivers the finished alloy ready for sale.

In making nickeliferous pig iron, pyrrhotite, carrying 40 percent of sulphur and two percent of nickel, is roasted to get rid of sulphur. This is never complete, and is a laborious job. Electrical smelting drops the sulphur at once to a fraction of a percent and a second melting delivers finished pig iron with 3.25 Ni, which finds a ready sale among steel makers.

That complex mixture of lead-zinc-iron sulphides carrying gold and silver, which has been the basis of more metallurgical schemes than any other, is a beautiful example of the electrical furnace doing what cannot be done otherwise. If the ores occur crystalline, they may be crushed and dressed, the lead separating by gravity, the iron and zinc by magnetic separation. But even with the best of work, the lead has some zinc and iron, the zinc some lead and iron, and the iron some lead and zinc. Only one metal is paid for, and any other value it carries is lost. In the electric furnace the raw ores from the mine, coarse and fine alike, are smelted without admixture of any kind whatever. Lead, zinc and sulphur volatilize and are caught and separated in condensing towers; copper, silver, gold, iron and silica form matte and slag. The matte is bessemerized to anode metal; the lead and zinc, with a second smelting, are made into finished metal.

Tin ores present many difficulties. The ores as they come to market contain many impurities, which in being slagged, carry a lot of tin with them. The case is complicated by the fact that tin functions as an acid to bases and as base to acids. Besides, the temperature of reduction of SnO_2 by C is high, and at this temperature tin volatilizes. The first ordinary smelting produces very rich slags, which after being re-smelted five times, still contain 3 to 5 percent of tin. If these slags be smelted in the electric furnace, slags result that carry but 0.25 percent tin, recovering the tin as metal, and besides, as a separate product, any other values.

Many ores of tungsten, manganese and chromium are low grade, their impurities being mostly iron and silica, frequently chemically combined. These may be separated and the fractions smelted, resulting in pig iron carrying a little of the other metal, and a high grade ferro-alloy of the more valuable metal.

Some of the more fusible metals volatilize badly at the

temperature of reduction of their oxides by carbon. Late improvements enable these metals to be reduced at low temperatures with no volatilization. For this work, the electric furnace is essential. In treating this subject, I feel it would be incomplete without some reference to power supply, the cost of which often determines the commercial adaptability of the electric furnace.

Central power stations are realising the desirability of an equalising load, and those who fully realise the situation will make very low figures, and still profit largely through serving electric furnaces. If the undertaking be of sufficient magnitude, an individual installation is desirable, and may be steam turbo-generator sets, or gas-engine units.

I am buying steam-generated current at 0.22 cent per kilowatt hour. Friends are operating gas engine sets at an inclusive price of 0.25 cent per kilowatt hour. Water power in Norway is being sold at 25 kroner ($6.50) per h. p. year, which is about one-third of the price of coal-generated current, but the first are in the manufacturing centers, while Norway has a freight of $1.25 per ton in and out.

London, England,
October 3, 1910.

DISCUSSION.

Dr. J. W. Richards: I hardly like the statement Mr. Ruthenberg made in regard to using the slag as a resistor, that the furnace should be built with a non-arcing voltage. I think you will find in using slag as a resistor that the current actually goes through the metal and practically only meets the resistance of the thickness of the slag above the metal. In all the furnaces which I know of, where electrodes are used, apparently dipping in the slag, there is always an arc beneath both electrodes, and the major part of the electric energy is generated by the arcs at the electrodes.

Mr. F. T. Snyder: I do not want to be a traitor in our own camp, but I think this is a good time to call attention to the

fact that the electric furnace load is not a desirable load for the central station power man and that where it is tied up on a large basis there is usually considerable trouble. It would be a very nice thing to advertise, if a fact, but it doesn't work out in practice the right way. The best plan is to put the furnace on the furnace user's own power, steam or water.

A paper read at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, Ill., October 13, 1910, President W. H. Walker in the Chair.

THE HIORTH ELECTRIC STEEL FURNACE.

By Joseph W. Richards.

This is an improved form of induction electric furnace, patented in Norway by Engineer Albert Hiorth (No. 19,955, May 14, 1909) and in the United States by C. W. Söderberg (No. 954,827, April 12, 1910). Mr. Hiorth has invented the main features of the furnace, while Engineer Söderberg has patented some details and has designed the furnace now in practical operation.

Some of the information following is taken from a lecture given by Mr. Hiorth at the Polytechnic Institution, Christiana, April 19, 1910, and part is from the personal observations of the writer at the works of the Jossingfjord Manufacturing Company, at Jossingfjord, Sogndal in Dalene, on the southwest coast of Norway, on September 5, 1910.

The natural conditions are particularly favorable in Norway for the development of electrometallurgical industries, since electrical power can be had in large quantities on ice-free deep-water harbors at $5.00 to $7.50 per horse-power year, with cheap ocean freights to and from all parts of the world.

In 1905, Mr. Hiorth and his father, Mr. F. Hiorth, took active steps to have a government commission appointed in Norway to inquire into the electrical production of iron and steel. The Polytechnic Institution of Christiana co-operated actively with them, with the result that a "Metallurgical Committee" was appointed by the government on May 24, 1907. This commission made a report in 1909 (Christiana, printed by H. Aschehoug and Co.), in which Prof. J. H. L. Vogt gave a short account of the Norwegian stock of iron ores, and the whole committee (C. A. Thorne, P. Farup and Prof. Vogt) reported upon the status of the electrometallurgy of iron and steel and upon the prospects of its future development in Norway.

Shortly after, the Messrs. Hiorth made inquiries of the holders

of patented electric furnaces as to license rights for Norway. The royalties demanded were not moderate, nor yet excessive, but the difficulty arose that the licensors required the Norwegian works to limit themselves to a low *maximum* output, as they did not wish the Norwegian product to compete with their own product in other countries; some even required that the Norwegian product should not be sold outside of Norway, thus intending to limit the Norwegian works to the small requirements of Norway and to prevent it entering into competition in the

Fig. 1. The Storage Reservoir.

world's steel markets. Under such conditions, an arrangement with foreign inventors was practically impossible, since Norwegian capitalists could not see the way clear to a proper development of the new industry.

Mr. Hiorth then constructed and patented, himself, a special type of electric furnace and offered it to Norwegian investors. As a consequence, the Jossingfjord Manufacturing Co. (Mr. Borger, president) became interested, developed a water-power sufficient for running a 10-ton furnace, and installed a 5-ton

furnace, which was just put into operation early in 1910. In many places on the west coast of Norway, electric current can be developed from water-power at a total installation cost of $25 to $30 per horse-power and at a total working cost of

Fig. 2. The Dam.

$4.25 per horse-power year. The plant at Jossingfjord falls within these conditions.

Figures 1 to 6 show the general details of the plant and its location. Mr. Jacob P. Nissen was engineer in charge of the power plant. The storage reservoir is 400 feet above the power

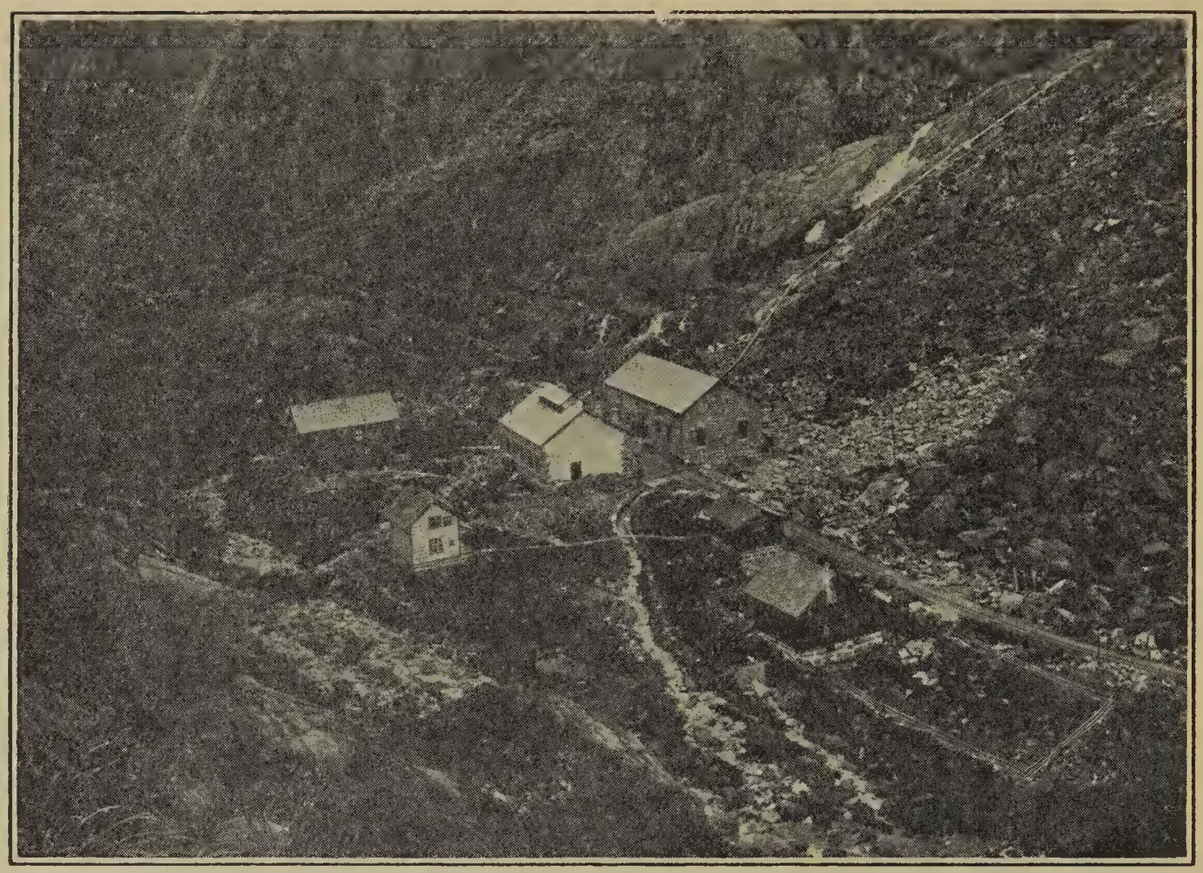


Fig. 3. The Plant, looking up-stream.

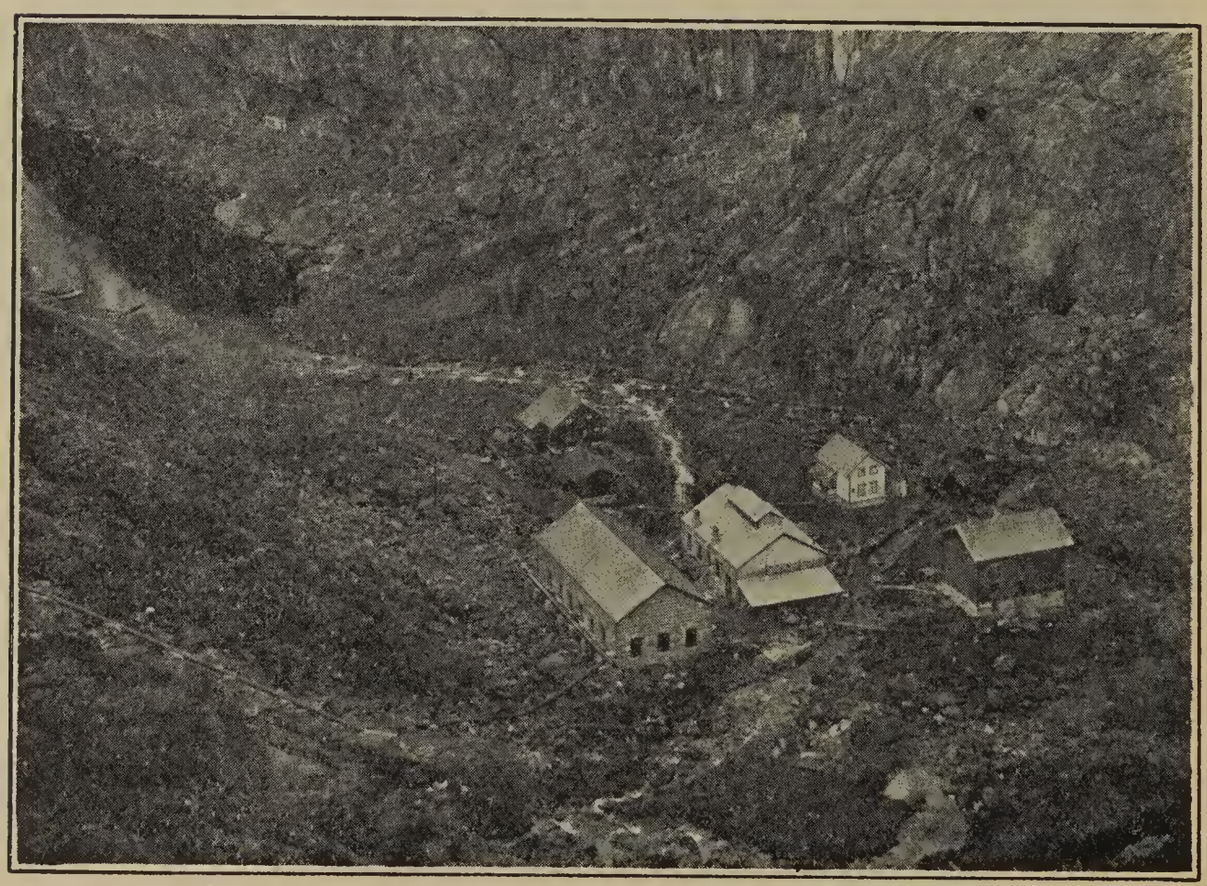


Fig. 4. The Plant, looking down-stream, showing landing place and fishermen's houses under the cliffs.

station; only rocky country was inundated by it. There is a minimum of 1,000 horse-power available. The 18-inch iron conduit brings the water to a Pelton wheel directly coupled to the generator, as shown. The latter delivers 400 to 500 kw., at 250

Fig 5. The Wharf and Tramway, looking Seaward.

volts, 12½ cycles. The copper cables to the furnace house are about 50 meters in length, and have a cross-section of 1,000 sq. mm. A tramway connects the works with a deep-water pier, distant about 200 meters.

The Hiorth electric furnace at present in operation at the

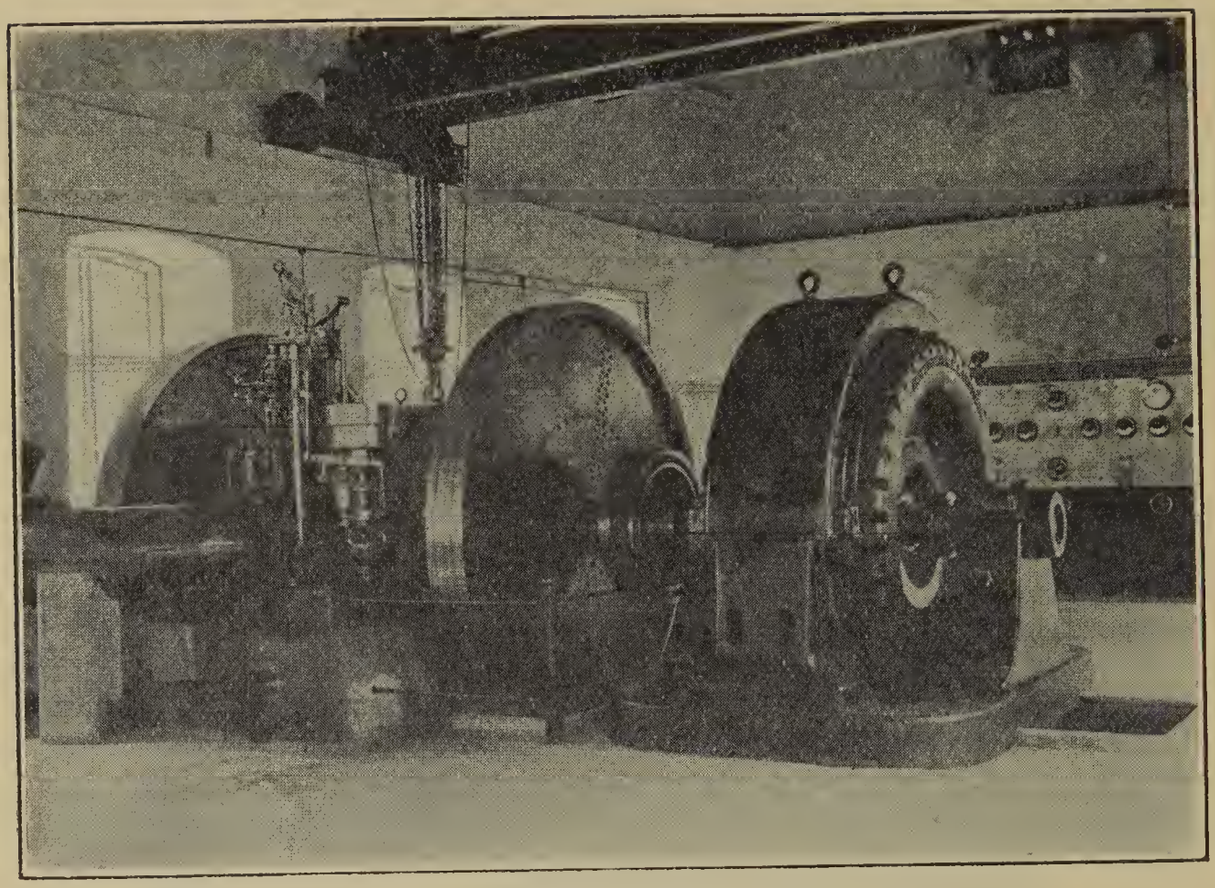


Fig. 6. The Pelton Wheel and Dynamo.

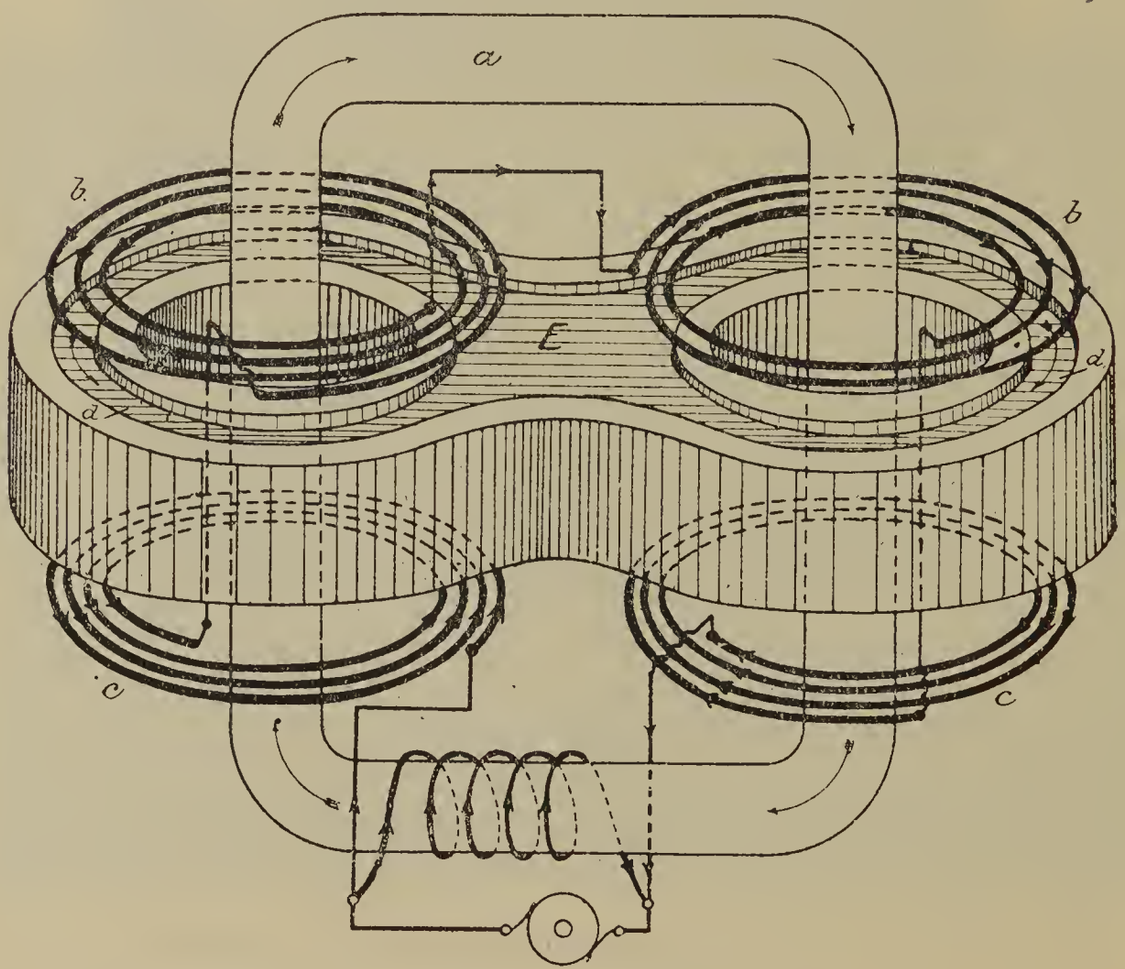


Fig. 7. Diagram of Electric Circuits.

Jessingfjord is a double-channel induction furnace, with the primary consisting of four coils connected in series. Fig. 7 shows diagrammatically the electrical principles, *E* being the steel bath, with its two channels *dd*, *a* the magnetic circuit, *bb* the upper coils, co-extensive with the heating channels, and *cc* the lower coils. The coils *bb* are suspended from pulleys with flexible connections, and when running, are close against the covers of the channels *dd*, but can be raised about 60 cm. (24 in.) when the covers are to be removed. The coils *bb* are un-insulated,

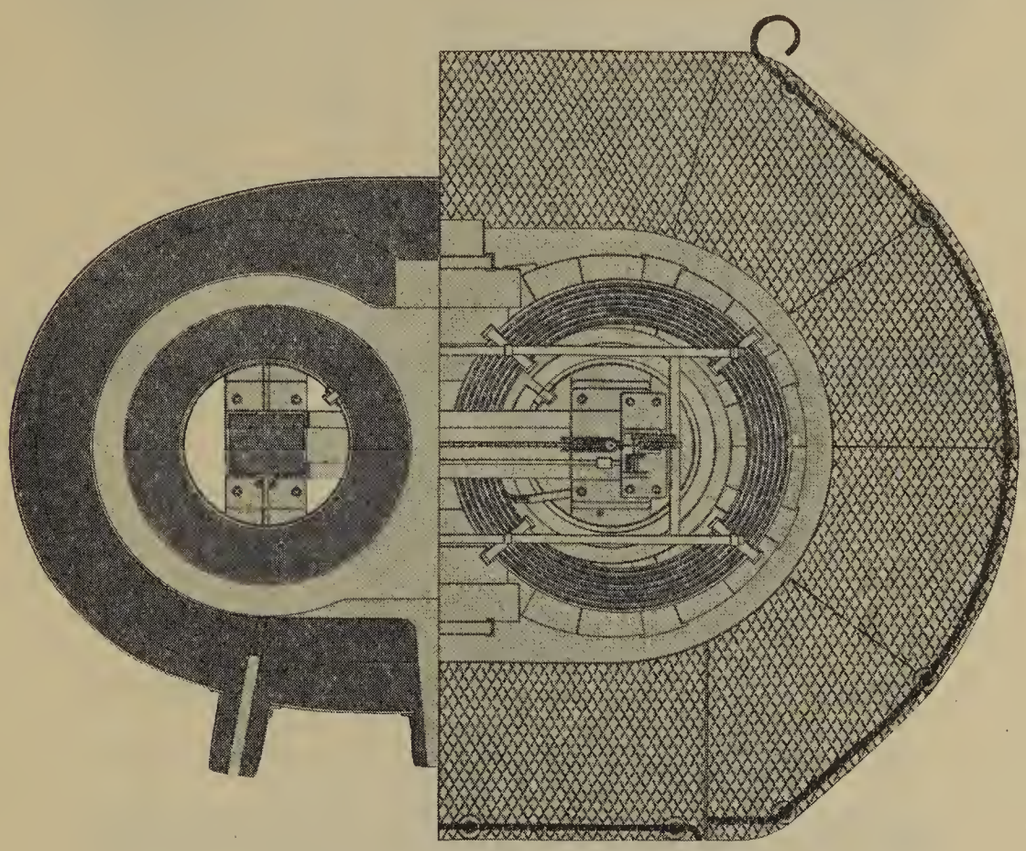


Fig. 8. Plan, half through channels and half on the platform.

bare copper bars, coiled spirally. The coils *cc* are hollow, water-cooled copper conductors, and in the actual furnace are embedded in the magnesite lining about 40 cm. (16 in.) beneath the channels *dd*. The voltage employed on the primary is so low that no particular precautions for insulation are needed, and no one can be seriously hurt by it. The space between the magnet *a* and the furnace wall is a clear 30 cm. (12 in.), which allows of the magnets (which weigh several tons) being bolted, firmly fixed, to the floor, while the furnace can be tilted for pouring. The central space *E* is 30 cm. (12 in.) wide in the middle, 60 cm.

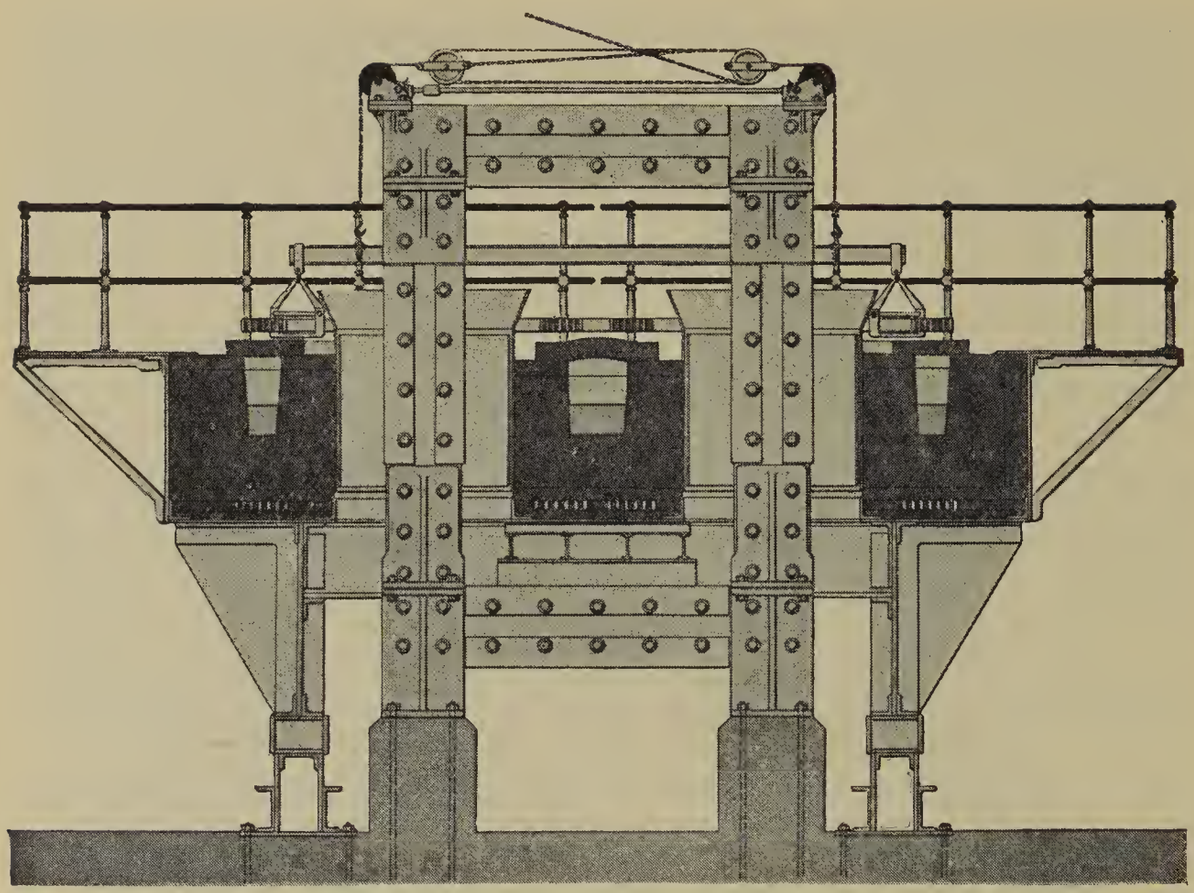


Fig. 9. Vertical Right-left Section.

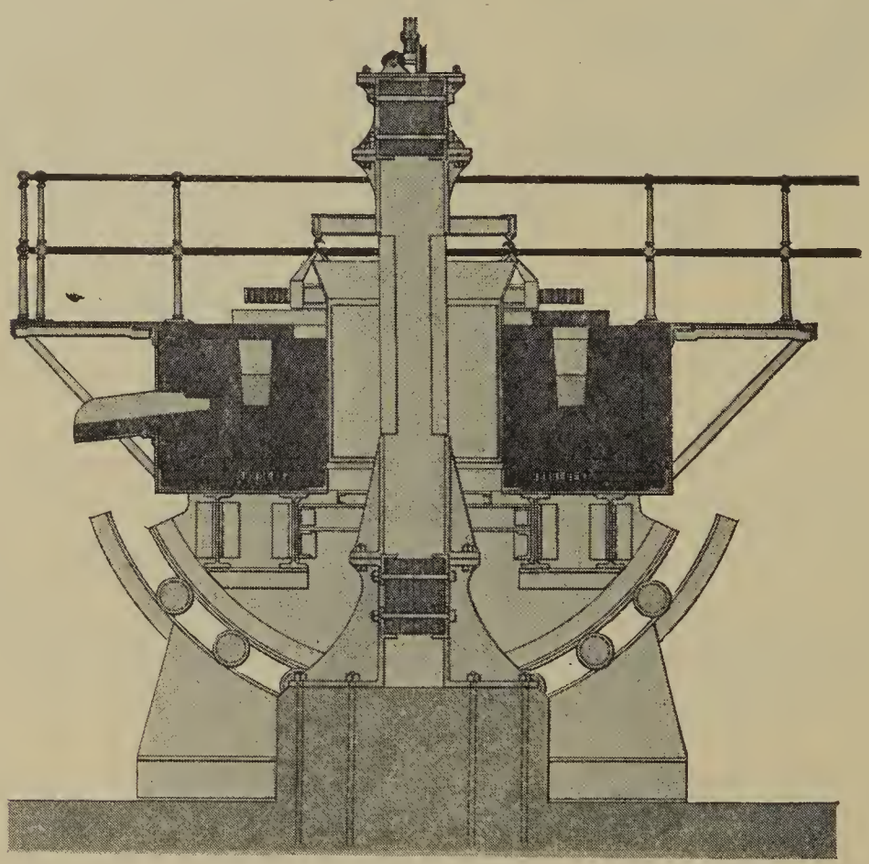


Fig. 10. Vertical Front-back Section.

(24 in.) wide at the sides, and nearly 2 meters (76 in.) long from front to back. It furnishes space enough to re-melt ingots or other scrap.

Fig. 8 shows a ground plan of the furnace; Fig. 9, a vertical section from right to left; Fig. 10, a vertical section from front to back, through one side, and Fig. 11, a vertical section from front to back, through the center, showing the furnace tilted.

On the occasion of the writer's visit, the running of the furnace was in charge of Mr. S. Cornthwaite, a Sheffield man, expert in

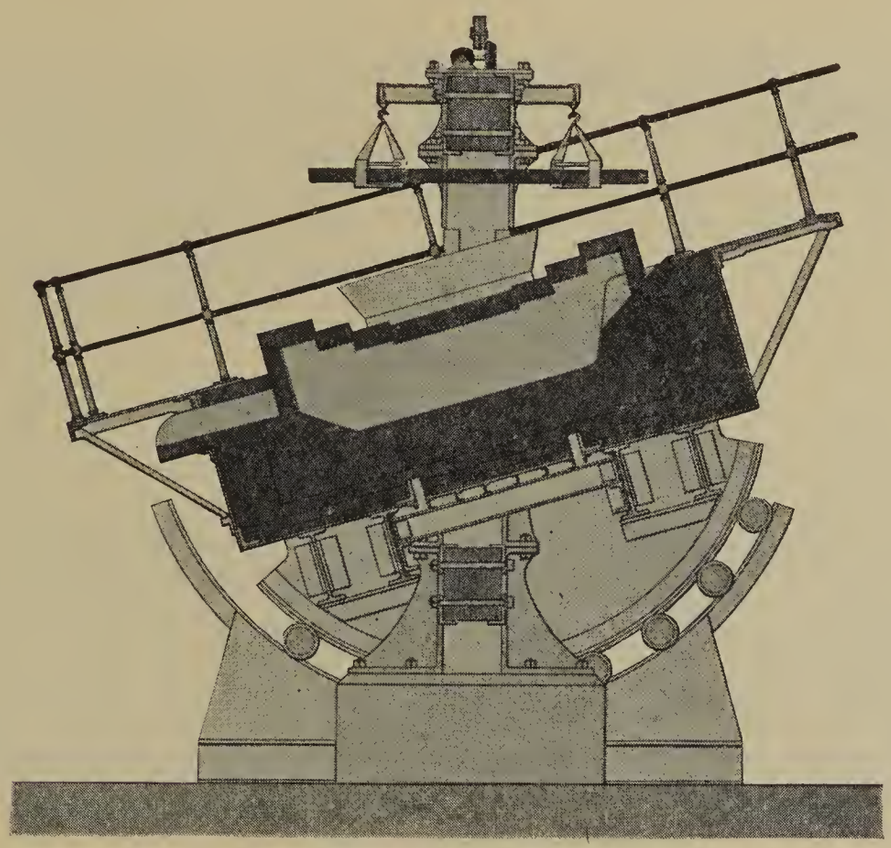


Fig. 11. Vertical Front-back Section; furnace tilted for pouring.

the manufacture and use of crucible steel. The furnace was lined with Veitsch Styrian burnt magnesite, which had been in position for seven weeks, during which it had been occasionally repaired. Norwegian magnesite had been tried and found to crumble badly; it had not been previously properly burnt. The covers were silica slabs, not sufficiently thick, however, to properly protect the melted steel from large radiation losses.

The materials being melted were the purest obtainable Swedish Dannemora pig-iron from the middle bed of the Dannemora ore

deposit, and Dannemora Walloon iron, costing, respectively $30 (108 kroner) and $75 (270 kroner) per metric ton. These are the identical materials used in Sheffield for crucible melting to produce the best quality of crucible steel. Yellowish-white blast-furnace slag, vitreous and glassy, from the Dannemora furnaces, was being used as a flux, mixed with fluorspar when greater fusibility was desired. The contents of the furnace being 5 tons, 3 tons were poured at a time and 2 tons left in to start the next charge, which then consisted of 3 tons of raw materials. The analyses of the raw materials and of some steels produced from them are given as:

	C.	Si.	Mn.	S.	P.
Dannemora White Pig	3.80	0.310	1.727	0.025	0.020
" Walloon Iron	0.107	0.013	0.068	0.010	0.009
Steel	1.42	0.130	0.322	0.010	0.019
	1.20	0.107	0.269	0.009	0.019
	1.02	0.112	0.301	0.008	0.021
	0.76	0.108	0.253	0.009	0.021
	0.67	0.108	0.288	0.006	0.021

The details of the heat run off when the writer was present were as follows:

12.20 P. M. In furnace, 2,775 kg. of previous steel, 1.00 percent carbon. Charged 1,000 kg. pig iron and 500 kg. Walloon iron. Current started.
12.30: Current 1800 A, 273 V, 380 kw. Cos. φ 0.77.
1.30: " 1840 A, 273 V, 395 kw. " 0.80.
2.00: " 2050 A, 265 V, 380 kw. " 0.70.
2.30: Charge melted. Average current 380 kw. for 2 hrs. 10 min. = 550 kw. hours per ton of metal melted.
2.30: Charged 350 kg. pig iron and 1150 kg. Walloon iron.
3.30: Current 2275 A, 270 V, 400 kw. Cos. 0.65.
4.30: Charge melted. Average current 400 kw. for 2 hrs. = 530 kw. hours per ton of metal melted.

[Assuming 300 calories necessary to melt 1 kg. of steel, the thermal efficiency of this melting operation is 55 percent, and the furnace radiation loss calculates out 180 kw., at this temperature. It was stated by Mr. Cornthwaite that it took about 170 kw. to keep the charge melted when the furnace was kept up to heat over night.]

5.30: Current 2370 A, 265 V, 395 kw. Cos. φ 0.63.
6.00: " 2425 A, 278 V, 400 kw. " 0.59.
6.15: " 2300 A, 280 V, 365 kw. " 0.57.

Metal now at casting temperature. Current used averaged 395 kw. for 6 hours, or 790 kw. hours per ton of steel. As low as 700 kw. hours has been reached in this 5-ton furnace on cold materials.

During the heat, there was added to the bath 35 kg. of 30 percent ferro-silicon and 8.7 kg. of 80 percent ferro-manganese; while 0.15 kg. of pure aluminium (= 0.005 percent of the charge) was added in the ladle.

The steel was poured into 20 cm. square ingots of ½ ton each, and cast beautifully. These ingots are being shipped to Sheffield

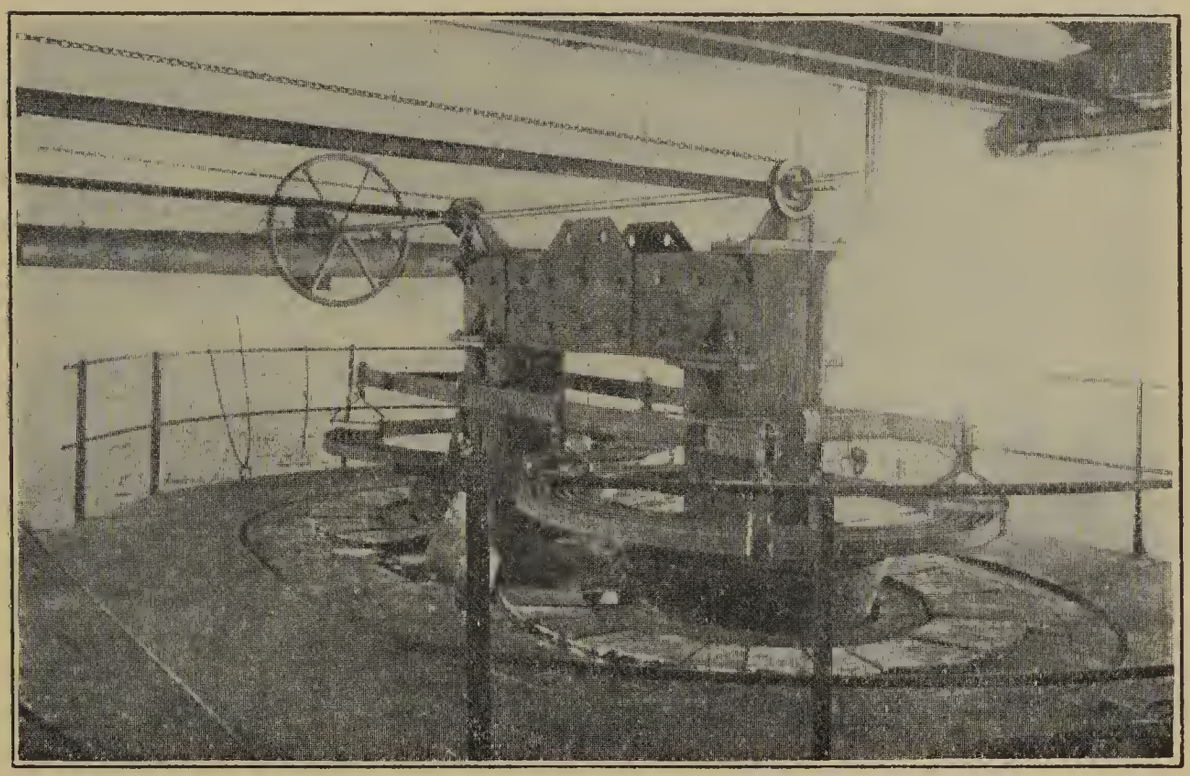


Fig. 12. Top View of Furnace.

for use in the steel works, and metal from this furnace has already given good service for razors, pocket knives, carvers, chisels, axes, files, reamers, taps, drills, turning tools (slow-speed), rock-drills, blacksmiths' tools and engineers' hammers. It sells in competition with crucible steel made from the same materials, the selling price of which is £60 ($293) per ton.

The labor required on this furnace per 24 hours was 1 head melter, 1 helper, 1 boy on each of two shifts, and 1 ladle man and 1 helper on one shift.

The capacity of the furnace is 12 tons in 24 hours, tapping a

3-ton heat every 6 hours. When in regular, steady running, 700 kw. hours are used per ton of cold charge melted.

The principle of the furnace is such that it may be increased almost indefinitely in size; a 50-ton furnace on this design is certainly practicable. In this 5-ton furnace the annular ring channels, 20 cm. (8 in.) wide by 45 cm. (18 in.) deep, are only filled 20 cm. (8 in.) deep with steel, and the narrowness increases the difficulty of working in the slag. Larger furnaces with wider channels will certainly be more free from this arching-

Fig. 13. Furnace in Operation; pouring a three-ton heat of crucible quality steel.

over of the slag, because it will fall of its own weight onto the metal.

It is distinctly worth while to remark that the temperature of the steel in the center compartment was fully as high as in the annular spaces, even just before the doors. This shows that, with proper heat-insulating covering over the steel, supplementary heating of the central bath is not a necessity. It appears to the writer that the difficulty heretofore met at this point is incidental merely to the smallness of the furnaces, and will disappear as larger furnaces are built. Figs. 12 and 13 show the furnace in action.

In conclusion, we may congratulate the Messrs. Hiorth and their very active staff on the high degree of success so far attained by their novel and yet very practical furnace—a furnace which has most of the advantages of the best induction furnaces without some of their serious disadvantages.

DISCUSSION.

MR. SEEDE: I would like to ask Dr. Richards what the frequency of the supply service is, and what the power service is, having two tons and five tons in the crucible.

MR. RICHARDS: The power factor of the furnace has varied around 75; it was 84, I think, on one of the test runs; the frequency was given me as 12½ cycles.

MR. CARL HERING: May I ask how it is started cold.

MR. RICHARDS: They put up originally a cupola furnace, to melt down some cast iron, in order to pour it into the furnace, and they tell me that they used it at first, but they have since abandoned its use. I cannot say just how they start it at present, unless they leave in enough metal in the bottom of the channels to form a starting ring.

MR. HERING: How about the expansion and contraction of the ring?

MR. RICHARDS: Possibly they have had difficulties with it. They said they had abandoned using the cupola, and had always left a ring of material in. The lining they had in it at the time I saw it had been running seven or eight weeks without being replaced, only requiring some patching in between the heats, so it could not have damaged the lining seriously.

MR. BENNIE: I would like to take exception to the notion that it is not possible in the ordinary type of induction furnace to charge ingots and other large pieces of metal. In a furnace that was run for sometime at Niagara Falls it would be found easily possible to do this by having a recess in the outer wall form-

ing the crucible, putting 4-inch or 6-inch ingots upright into this recess after the bath had been formed. These ingots rapidly melted down, and owing to the rapid movement of the bath in induction furnaces we were unable to detect any local cooling due to the enlargement of the bath in the vicinity of the recess.

Mr. Frary: May I inquire how the power factor varies with the load, whether it decreases as markedly with overload as it increases with the ordinary electrode furnace.

Mr. Richards: I have not the details of that; it might be figured out, however, from the current readings given.

Mr. Lloyd: Considering the question of the cost of power, it is always interesting to know how this is figured. One report that I saw lately on a four-million dollar investment had about $35,000 allowed for depreciation, for six months, or less than 2 percent per annum. I would like to ask Prof. Richards what allowance was made in this case for depreciation, and what percent interest was figured.

Mr. Richards: My remembrance was they allowed five percent depreciation per year, and figured interest at six percent.

A paper presented at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, October 13, 1910, President Wm. H. Walker in the Chair.

REDUCTION OF TIN DROSS IN AN ELECTRIC FURNACE.

By R. S. Wile.

Electrical heat was resorted to for the smelting of tin dross because of the fact that the heat could be internally applied to the slag, which is on the bottom of a shaft-type of furnace, thus enabling the dross to be thrown on top of the slag instead of being mixed with it as is done in the old style of furnace. The dross, being on top, comes in contact with the slag only at the point of reduction. The liberated gases filter through the dross, while any tin oxide which is volatilized is condensed in the colder portion of the dross, which, as I have said, is on top of the slag. The globules of tin produced in smelting pass downward through the slag and lose most of the impurities, so very little refining of the resultant product is necessary.

In operation, the top carbon, which is movable, is brought into contact with the lower carbon, which is stationary, and an arc formed. The slag is fed in and melted, and the carbon is raised until the desired amount of slag is added. The dross, mixed with the right percentage of carbon, is added, and the tin tapped from the bottom from time to time. The loss of tin has been kept as low as 0.25 percent, and the average below 1 percent. The amount of tin recovered varies largely on account of the varying percentages in the drosses treated. The average is about 2,500 pounds (1,100 kg.) per day.

The plant consists of two furnaces, connected in series, both being 20 inches (50 cm.) in diameter and 80 inches (200 cm.) high inside, two 50 kw. transformers and necessary electrical apparatus. In operation they consume about 44 kw. During the run it is desired to keep the amperage as near constant as possible, the voltage varying. At the start the voltage of each furnace is about 80, but toward the end, as the slag becomes less refractory, due to the combination of the iron and zinc of

the dross and the slag, the voltage of each furnace will drop as low as 45-50. This and an analysis of the slag denotes the end of the operation, and the slag must be drawn out and new put in. This is done alternately with each furnace. The furnaces run continuously until time to be relined, which is about every three or four months.

Riverside Metal Refining Co.,
Connellsville, Pa.

DISCUSSION.

Mr. Richards: I would say, Mr. Chairman, that I think this little paper suggests a rather general method of reducing. Mr. Wile is at Connellsville and is connected with a tin plate works which makes a good deal of tin dross, and he advises this method for utilizing the tin dross for the tin works. The idea, however, is probably applicable to the electric smelting of other drosses and ores.

Mr. Frary: I would like to ask, if it is not a trade secret, the composition of the slag which is mentioned as being used in the reduction. It is not mentioned in the article and I think most of us would like to know.

A paper read by Mr. A. B. Marvin, at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, Ill., October 13, 1910, President W. H. Walker in the Chair.

CAST COPPER OF HIGH ELECTRICAL CONDUCTIVITY.

By E. Weintraub.

The production in the foundry of pure copper castings mechanically sound and possessing an electrical conductivity comparable to that of pure forged copper has been an important problem ever since the development of electrical machinery and apparatus. The literature as well as the patent files are replete with descriptions of methods for the accomplishment of this result. Secret compositions, warranted to give high conductivity copper, were and are being sold to foundrymen, and there are but few foundry foremen to be met with who do not claim to have, some time or other, obtained the desired result by adding "phosphorus" or similar material. Obstinately, however, the casting of high conductivity copper refused to make its entrance in the foundries, and we may assume that there were good reasons for it.

The cause of the difficulty of producing sound pure copper castings has been sufficiently well understood for a long time. Molten copper has the property of dissolving gases and of setting a part of these gases free on cooling. This produces pinholes and even big cavities. The casting obtained is therefore mechanically unsound, and has naturally a low electrical conductivity.

The elimination of these dissolved gases presents but little difficulty. It is sufficient to add one of the well-known deoxidizers, such as zinc, magnesium, phosphorus, etc., in small quantities to bind the oxygen or the gaseous oxygen compound chemically. Copper castings free from blowholes are thus easily produced. The electrical conductivity of the copper thus produced is, however, as a rule, low, and this because all the *deoxidizers used had also the property of combining with copper,* and the remarkable rate in which the conductivity of copper drops when small amounts of impurities are alloyed with it is well known. The amount of the gaseous oxygen compound dissolved in

copper during the process of melting is a variable quantity and is distributed throughout the whole mass. It is therefore practically impossible to add the deoxidizer in such a way as to eliminate oxygen completely without, at the same time, alloying it, to a certain degree, with the copper. Accordingly the conductivity of the resultant product was a matter of accident. In the laboratory sometimes good results were obtained, but they were hard to duplicate, and the transfer to the foundry was always a disastrous experiment.

It seemed to me that what was needed for the solution of the problem was the finding of a deoxidizer which would have no affinity for copper (at least, at the melting point of the latter) and which, therefore, could be added in excess with impunity.

While carrying on the work of the isolation of the pure element, boron, and its fusion, the lack of affinity of this element for copper has forcibly impressed itself on my mind. Boron has, at the melting point of copper, a great affinity for oxygen, nitrogen, etc., and it occurred to me, therefore, that boron ought to be the ideal substance for deoxidizing copper.

Pure boron as prepared by methods described by me in paragraphs 2 and 4 of my article* can, by this time, be produced in large quantities, and is rather inexpensive for uses based on its electrical properties. For casting copper, however, its price would probably be too high.

In the course of the investigation mentioned I had prepared, however, an amorphous powder which contained as essential impurity only a certain percentage of oxygen, and which I termed "boron suboxide." This substance is prepared by a modification of the reduction process of boric anhydride by magnesium. Obviously for the purpose of eliminating oxygen from copper without introducing any impurity capable of alloying with copper, this boron suboxide would be as good as pure boron, or perhaps better, on account of its being obtained in form of a very fine powder.

This substance was used in the first experiment. The very first attempt was successful. A perfectly sound bar was obtained with a conductivity of 94 percent; 0.1 percent of the weight of the copper was added. Further experiments showed that the

* Transactions American Electrochemical Society. **16**, 165 (1909).

amount of boron suboxide could be reduced to 1/30 percent, and also that the addition of a large excess, say, of 1 percent, did not diminish the conductivity or change in any way the mechanical properties of the cast copper.

Here was, therefore, a method which could be put into the hands of any foundryman and which would always give good results, provided the copper (ingots or scrap) melted down was pure metal.

A further simplification could, however, be introduced into the process. The reduction of boric anhydride by magnesium, the first being in excess, gives a product containing magnesium borate, boric anhydride and boron suboxide. While the last one is the active agent, the first two are harmless. In fact, the presence of boric anhydride and magnesium borate is even an advantage, as the addition of a larger mass of material makes the operation easier; also the boric anhydride would probably dissolve the copper oxide and bring it to the surface as copper borate. It is therefore unnecessary to submit the direct product of the reaction to chemical treatment for the purpose of isolating the boron suboxide. It is sufficient to grind up the mixture into coarse grains and use an amount of it which contains the necessary amount of boron suboxide.

The foundry practice at present is to add 1 percent to 1½ percent of this material, which is equivalent to 0.08 percent to 0.1 percent of boron suboxide.

The properties of the material obtained are as follows:

The electrical conductivity obtained can be as high as 97½ percent if the copper melted down is perfectly pure. In the foundry, where the scrap copper which is melted down cannot always be very carefully selected, a conductivity of 91 to 95 percent is obtained, and a guarantee of 90 percent is at present given.

The resultant casting is readily machined; fears which were entertained on this subject did not materialize, and the engineers using the material have not complained on this account. The mechanical properties are as follows:

Tensile Strength	Elastic Limit	Elongation	Red. in Area
24350 lb. per sq. in.	11450 lb. per sq. in.	48.5%	74.49%
17.0 Kg. per sq. mm.	8.0 Kg. per sq. mm.		

Castings are being made of all shapes and sizes with no more difficulty than in the case of brass. Sand and iron moulds can be used, and for standard articles the latter are preferred.

The use of cast copper lies in two different directions: 1. Replacing forged copper. In this case a great saving in cost is often obtained. 2. Replacing alloys of copper. The gain in conductivity allows the reduction in bulk and thus a saving in material.

The use of this material is spreading as the engineers get better acquainted with it, and is already of very considerable magnitude. It is interesting to note that, in spite of the fact that cast copper has lower conductivity than forged copper, in many cases, as, for instance, in case of current transformers, the effect of higher conductivity is obtained by substituting it for forged copper. This is due to the fact that in casting a chance is given to eliminate riveted, screwed or soldered joints, whereby a number of poor contacts are avoided. Not only this, but the elimination of joints often insures a better operation.

The cost of the boron added is small; at the present prices of magnesium and boric anhydride, the cost per pound of copper is less than .75 of a cent.

The success with "boronizing" copper, as it is now called in the foundry, suggests new lines of work which I have taken up lately.

Among these I mention:

First, the addition of boron to different copper alloys.

Second, the replacing of the poling operation in the process of refining copper by a "boronizing" operation.

In conclusion, I want to express my appreciation of the excellent work done by my assistant, F. A. Kroner, without whose energy and foundry experience the technical and commercial success of the process described would have been greatly delayed.

Research Laboratory, General Electric Company,
West Lynn, Mass.

DISCUSSION.

Mr. E. A. Sperry: I wish to express my appreciation of this excellent paper. Cast copper has been known to be very desirable for a great many purposes, yet for many years we have worked along with castings full of blowholes and with "dropped" copper castings. As you probably all know, after they have been cast, the usual practice up to the present time is to compress them with drop and die so as to close up the blowholes and render them more dense and electrically conductive. This work certainly will be appreciated by those who have had experience in trying to use cast copper for electrical purposes. There is one question I would like to ask and that is the method of making the casting about the bars. Is it necessary to heat the bars at the time of pouring?

Mr. John A. Seede: I think the importance of Dr. Weintraub's process is brought out more strongly by the fact that the production of a sound copper casting is practically independent of the operator. When we consider that ordinary copper castings, even with the use of some of these purifying mixtures, have a conductivity of something like 25 percent to 40 percent, I think that the increase to 95 percent is a great advance.

A paper read at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, Ill., October 13, 1910, President Wm. H. Walker in the Chair.

METHOD FOR DETERMINING THERMAL CONDUCTIVITIES.

By Carl Hering

Methods for calculating and designing electric furnaces to reduce the heat losses to a minimum seem to have developed faster than our knowledge of the physical constants on which such design must be based. There is therefore now a need for more accurate determination of these thermal constants. This is of far greater importance for the proper designing of electric furnaces than it was for gas or coal furnaces, on account of the greater cost of the heat. The losses in the electrodes, which are generally good thermal conductors, have been discussed in various papers by the writer,[1] in which it was shown how they could be reduced to a minimum,[2] and the constants for calculating the best proportions and the losses have been determined.[3] For calculating the losses thru the walls, however, there still remain to be determined, more accurately than before, the thermal constants for those refractory thermal insulating materials as are used for such walls, over the ranges of temperatures involved.

The purpose of the present paper is to suggest a new method of determining these constants for insulating materials over the desired ranges of temperatures used in practice. The underlying principles of this method are as follows.

In view of the numerous difficulties encountered in the accurate measurements of flows of heat as such, the writer suggested generating the heat electrically and measuring it while it is still in

[1] The Design of Furnace Electrodes; Electrical World, June 16, 1910, p. 1598. The Proportioning of Electrodes for Furnaces; Proceed. Am. Inst. Elec. Eng., March, 1910, p. 285. Empirical Laws of Furnace Electrodes; these Trans., Vol. 17, (1910) p. 171. Properties and Behavior of Furnace Electrodes; Met. and Chem. Eng'ing, March, 1910, p. 128. Chilling or Heating Action of Furnace Electrodes *vs.* Least Electrode Loss; Ibid., April, 1910, p. 188. Improving the Output and Efficiency of Existing Electric Furnaces; Ibid., May, 1910, p. 267.

[2] Laws of Electrode Losses in Electrical Furnaces; these Trans., Vol. 16, (1909) p. 265.

[3] Determinations of the Constants of Materials for Furnace Electrodes; these Trans., Vol. 17, (1910) p. 151.

the form of electrical energy and before it is converted into heat, as it may then be measured very easily, quickly and accurately by means of a voltmeter and an ammeter; this was the basis of the method used in his determination of the thermal constants of electrodes. The efficiency of conversion of electric energy into heat may safely be taken as 100 percent, provided such factors as the Peltier and the Thomson effects, electrolytic decompositions, etc., which generate counter electromotive forces, or chemical changes involving thermochemical reactions, or physical changes involving energy reactions, can be neglected, eliminated or accounted for. Among the latter may be mentioned the conversion of moisture into steam.

Such a method is available, however, only when it is certain that all or virtually all of the heat energy of the electric current actually passes thru the whole length of the sample piece under test, that is, when no appreciably large part is lost prior to or during its passage thru the sample, as the formulas are based on the actual flow. This means perfect or nearly perfect heat insulation on the sides of the sample piece which are parallel to the flow of heat. But such a thing as even a moderately perfect heat insulating material is unknown, and it is in this feature that a flow of heat differs so greatly from a flow of electricity, and is more like a magnetic flux. Even a vacuum, which is such an excellent thermal insulator for convection heat, fails absolutely to stop the flow of radient heat; absorbing radient heat after it has left the body, of course, would not answer.

In view of nature's deficiency in not providing us with a material which insulates thermically, there seem to be open to us only two methods. One is to surround the body under test with another heated from the same or other sources to the same temperatures as the adjacent parts of the sample, or, in other words, the heat gradient in the surrounding body is made the same as that in the body under test; this is the way in which it was done by the writer in the determination of the thermal constants of electrode materials. The second possible way is to so shape the test piece that it has no lateral sides at all, in which case there cannot, of course, be any lateral leakage of heat; this is the means to be used in the present test, and is accomplished in its most perfect form by shaping the test piece in the form of a

hollow sphere, in which the heat flows from the inside to the outside.

Another important feature of this method is that it should enable the thermal conductivities to be determined not only as the average between zero and a given high temperature, as usual, but also between any two high temperatures, as it seems from our present knowledge that in the usual refractory materials the thermal conductivity becomes far greater at the higher temperatures, and, if so, it might lead to grave errors to assume that their good heat insulating properties determined between a low and a high temperature, as usual, applied correctly when both temperatures are high. A method was described by the writer[4] by means of which the conductivity between two high temperatures may be correctly calculated from those between zero and each of the two high temperatures without assuming any law of variation; but it is somewhat like determining a small length by taking the differences between two much greater lengths, a very slight error in either of the two latter would make a very great percentage error in the former. Unless, therefore, the two conductivities had been determined very accurately, which is not likely, such a deduction from them might be unreliable.

The method which is the subject of this paper was suggested very briefly in one of the writer's previous papers.[5] In its ideally perfect tho not very practical form, it consists in shaping the sample piece in the form of a hollow sphere. The inside is filled with a good heat conducting material, like a molten metal, which is heated electrically, say, by means of an insulated coil of wire. The outside is surrounded by any suitable liquid, preferably kept in good circulation as it receives the flow of heat; this liquid is provided with a cooling worm which carries off the heat exactly as fast as it arrives thru the sphere. The temperature of the inside and outside surfaces of the sphere are determined by means of pyrometers, thermometers or thermocouples, and the electric energy set free in the inside by means of an ammeter and a voltmeter. The sphere might be made of two halves without introducing an error due to the high thermal resistance of the joint, because the heat flows parallel to and not across this joint.

[4] Heat Conductivities in the Calculation of Furnaces. Electrochem. and Met. Industry; Feb., 1909, p. 72.

[5] Heat Conductances Through Walls of Furnaces; these Trans., Vol. 14, (1908) p. 215.

To conduct the test, pass the electric current until the temperature in the inside has reached the desired high value, and cool the outside liquid until it has reached the desired lower value.

When the stable state has been reached, read off the watts and the two temperatures; the dimensions of the sphere are supposed to have been measured accurately. The heat carried off by the cooling worm need not be measured, but if it is, it will answer as a rough check, the electrical determination being unquestionably by far the more accurate.

It is of the utmost importance to be sure that the stable state has been reached, for if the heat in the whole system increases or diminishes during the readings, the error in the deduced result may become quite great. It would, therefore, no doubt, be much better to keep the watts and the stream of cooling water constant and to let the temperatures become what they will than to try to obtain any two desired temperatures; the results for any specific temperatures can then best be determined by a curve drawn thru the series of values given by a series of tests. During the first heating it will probably take an hour or two before the stable state is reached after the watts and the cooling current of water have begun to remain constant.

From this data the thermal conductivity is readily calculated from the following formula, which is rigidly correct:

$$k = a \frac{W}{T} \qquad (1)$$

in which a is a constant, calculated once for all for each test piece, and is equal to

$$a = \frac{l}{\sqrt{S\,s}}$$

k is the thermal conductivity in watts for 1 inch cube for one degree C.; W is the energy in watts set free in the inside; l is the thickness of the shell in inches (that is, the length of the path of the flow of heat); T is the temperature drop in the shell in centigrade degrees, that is, the difference between the inside and outside temperatures, and S and s the outside and inside surfaces (or cross-sections of the path of the flow of heat) in square inches. Or if l, S and s are in centimeters, k will be in

watts for 1 cm. cube. It will be noticed that the average cross-section of the path is the geometric mean between the two, and not the arithmetic mean, as is more generally assumed (for a discussion of the difference, see the reference above cited on "Heat Conductances Through Walls of Furnaces").

It will also be noticed that this test gives the absolute thermal conductivity, and not merely relative values, like most other methods. The value is here represented in terms of watts for 1 inch cube (or 1 cm. cube) because this new unit simplifies the subsequent calculations of electrical furnaces; if it is desired to express this conductivity in gram calories per second for 1 inch (or cm.) cube, multiply this k by 0.23888. When the conductivity is in watts, then the loss of heat through the walls or portions of the walls of a furnace, expressed in watts, is simply

$$W = \frac{k\,T\,S}{l} \qquad (2)$$

in which S is a certain average cross-section of the walls perpendicular to the path of the heat flow; the correct average to use was fully discussed in the paper just cited.

Attention is here called to the fact that the conductivity may vary with the temperature, in which case it would be different in different parts of the sample, and perhaps this variation is very great in some of the refractory materials. It is known, for instance, that the electrical conductivity of some of these materials varies enormously with the temperature, as is well shown in the Nernst lamp glower; and it may be that the thermal conductivity accompanies the electrical in those marked variations. It may therefore be well to point out here that the present method is entirely independent of such variations and involves no assumptions as to any constancy or any particular law of variation in that material; it applies to all cases, being quite as correct for wide variations as for absolute constancy. The reason for this is that the value of k obtained from formula (1) is, like in all such formulas, the true and correct average or effective mean for that range of temperature, that is, it is that conductivity which an *equivalent* piece of material would have whose conductivity is constant over that range of temperature, and which *as a whole* acts just like the sample. It is this very value which the designer

needs, hence the method gives just what is wanted. All considerations of the variations with temperature are therefore eliminated by this method.

It seems, therefore, that the rigidity of the method is entirely independent of these variations or of the heat gradient, provided only that the heat gradient for any one material is similar in the furnace wall to what it was in the sample, no matter what shape it has or how greatly it may differ in different materials. Hence, apparently the only departure from strict mathematical rigidity is that the heat gradient in a conical element of such a spherical test piece may be slightly different from that in a truly cylindrical or prismatic solid bar to which that value might be subsequently applied; or that the heat gradient may be slightly different when the ratio of the wall thickness to the distance from the apex is not exactly the same. But, in the first place, this possible error would probably be extremely small (probably only a small percentage of a small percentage), and would therefore be negligible in practice, especially when the test piece is a hollow cylinder as recommended below, and when its walls are relatively thin. And, moreover, when these constants are applied to furnace walls, for which they are mainly intended, the elemental parts are always pyramidal or conical, and are never truly cylindrical or prismatic bars, and the heat gradients would therefore be likely to be almost if not quite identical with those in the sample; hence the constants obtained would apply to furnaces even better than if the test pieces had been a solid cylindrical bar. The present method, moreover, possesses the advantage that the conductivity may be determined between any two temperatures, even when both are high; hence it enables the law of variation to be determined if desired, and probably with considerable accuracy.

While the hollow sphere is the ideally perfect form to use in this test, because it is absolutely symmetrical all over, it is probably also the most impractical. Theoretically a hollow cube would be as perfect, but in practice, errors would be likely to arise, due to the fact that the temperatures at the outside edges and corners would probably be slightly lower than at the middle of the faces. The same formula (1) is rigidly exact for cubes also. The plugged opening into the cube, or the surfaces along

which it is parted, should be approximately parallel to the lines of flow of the heat.

Presumably the most convenient form of the test samples would be a cylindrical cup rounded at one end and open at the other, as shown by *C* in the adjoining Fig. 1, which is a diagrammatic vertical cross-section of the whole apparatus. The inside is nearly filled with the heating liquid containing the heating coil; the outside vessel is nearly filled with the cooling liquid

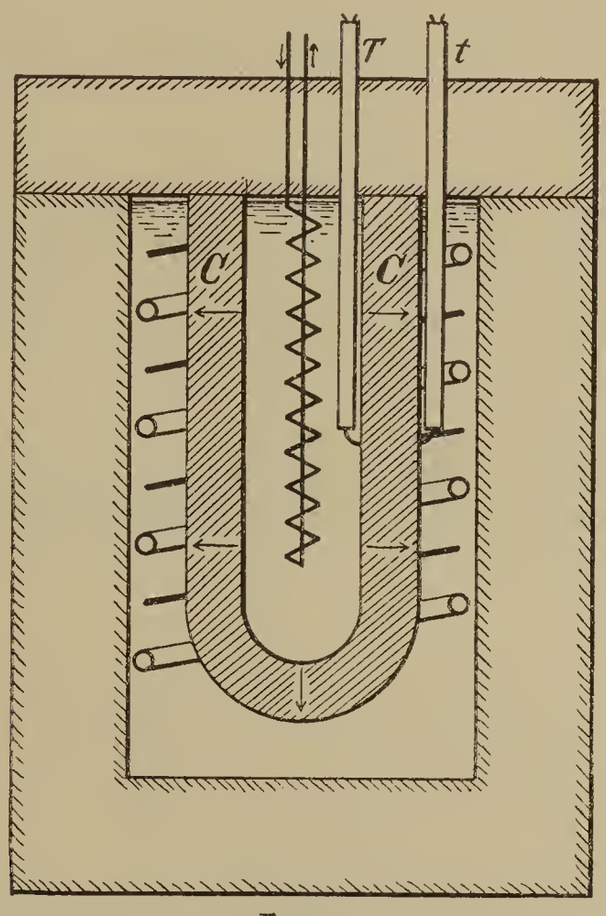


FIG. 1.

and its cooling worm. *T* and *t* are the two temperature measuring instruments. When both temperatures are very high, the outside liquid may also be a molten metal, in which case it had better also be provided with a heating coil to save the time it would take to heat it with the heat which has to pass thru the test piece; but the heat generated in this coil, of course, need not be measured.

The objection to this form is that there will necessarily be some loss of heat thru the cover over the top. This can be made relatively small by making the cylindrical cups long relatively to

the diameter. It can furthermore be allowed for by bringing the inside and outside liquids to the same temperature, namely, the high temperature of the inside liquid (this requires a heating coil in the outside vessel), then measuring the watts generated in the inside of the cup to keep the temperature constant after the stable state has been reached. As there will then be no flow thru the walls of the cup, all these watts will represent the loss thru the cover over the top, and should therefore be subtracted from the watts measured in the subsequent tests as a constant loss. It would doubtless be sufficiently accurate to assume this loss to be proportional to the respective temperatures of the other tests.

Care should, of course, be taken to mould or grind the test cup so that its wall thickness is the same thruout. For testing loose, granular or fibrous materials, like infusorial earth, sand, asbestos, magnesia, etc., the cup may be made of two thin shells of iron, the material to be tested being filled in the space between them.

For such a cylindrical cup, with its one end rounded off to a half sphere, the value of the thermal conductivity k is as follows:

$$k = a \frac{W}{T} \tag{3}$$

in which a is a constant, calculated once for all for each test piece, and is equal to

$$a = \frac{l \text{ com. log. } D/d}{2.7288\, l L + 1.5708\, D d \text{ com. log. } D/d}$$

k is in watts for 1 cubic inch or 1 cubic centimeter, depending upon the linear units used for the other quantities; W represents the watts generated in the inside of the cup when the stable state has been reached (after deducting the loss thru the lid); L is the length of the straight part of the cup, down to the beginning of the hemispherical bottom; l is the wall thickness of the cup; D and d are the outside and inside diameters, respectively; T is the drop of temperature in centigrade degrees between the inside and outside surfaces of the cup; all linear dimensions must be either in inches or in centimeters, and the value of k will then refer to inches or centimeters respectively. The constants

in this formula are purely mathematical and involve nothing empirical. This formula is deduced from the rigidly correct laws given below.

If instead of a hemispherical base the cup has a flat bottom, the corresponding formula will become slightly different. It can readily be deduced, however, and the one above given can be checked, if desired, from the following three fundamental formulas taken from the writer's previous paper, above referred to.

For a frustrum of a hollow sphere,

$$R = \frac{r\,l}{\sqrt{S\,s}} \tag{4}$$

For a whole cylindrical shell with open ends,

$$R = \frac{r}{2\,\pi\,L} \times nat.\ log.\ \frac{D}{d} \tag{5}$$

For a pyramidal frustrum whose two parallel sides are perpendicular to its axis and whose cross-sections (perpendicular to its axis) vary proportionately with the square of the axial distance from the apex,

$$R = \frac{r}{\sqrt{n}}\left(\frac{1}{\sqrt{s}} - \frac{1}{\sqrt{S}}\right) \tag{6}$$

it therefore applies to any one of the six sides of a rectangular furnace.

These are taken to be the rigidly correct formulas for the electrical resistance R, and apply, therefore, equally well to the thermal resistance. The lengths and surfaces should be in the same units thruout, either inches or centimeters, the resistivity r being then in terms of a cubic inch or a cubic centimeter. S and s are the large and the small surfaces, respectively, that is, the two extreme cross-sections of the path of the current; l is the length of this path, that is, the thickness of the wall; L is the length of the cylinder; D and d are the outside and inside diameters of the cylinder; n is the rate of flare of the pyramid, such that $S = nP^2$, in which P is the axial distance from the apex to that surface.

These formulas are here accepted to be rigidly correct merely

for a uniform resistivity. Whether or not they are also rigidly correct when the resistivity varies along the path of the current need not be considered here, as it is certain that the conductivity determined by means of them is the true mean, average or effective value over that range, no matter how great the variation may be in different parts; that is, it is that conductivity which a body of the same size and shape and of uniform conductivity would have, in which the flow of heat or electricity is the same. It is this true average or mean value that is wanted, and it is this value that the present method gives.

A possible objection to this method, which it has in common with others, lies in the possible high resistance at the contact surfaces between the liquids and the material under test. It is known that such contact resistances may be very high, perhaps far higher than that of the sample itself. In that case it would cause grave errors to assume that the temperatures of the two liquids are those at the two surfaces of the test piece. It is believed, however, that if the liquids are such as will "wet" the surfaces of the test piece, like fused salts, for instance, or if the sample can be electroplated and then tinned, the liquids being then a metal which combines with tin,—this contact resistance may be assumed to be eliminated, especially if the thermal resistance of the sample is high (thick walls) relatively to that of the two liquids. Otherwise the points of the two thermocouples may be placed in contact with the surfaces and shielded from the liquids.

The writer has not yet had an opportunity to carry out this method, and it is therefore offered here merely as a suggestion; but he has carried out[6] the somewhat analogous one adapted to determining the thermal conductivity of good electrical conductors, such as electrodes, and found it to be very satisfactory and subject to greater accuracy than is necessary for the constants used in practice.

Philadelphia, August 27, 1910.

[6] Determinations of the Constants of Materials for Furnace Electrodes; these Trans., Vol. 17, (1910) p. 151.

DISCUSSION.

Mr. J. W. Richards: In my laboratory, Professor Landis and some of our students have used this method. Some six months ago they started making experiments in this way, and we constructed and made measurements upon spheres of the materials. It worked experimentally satisfactorily, and measuring the temperatures at different distances through the sphere we had the heat gradient. The total heat flow and conditions were steady, being simply the electrical heat generated in the center of the sphere. It was interesting to note that for a ball of graphite the heat conductivity was so great that it was almost impossible to measure the difference between the temperature in the middle and the temperature on the outside. It became to within a few degrees as hot on the outside as it was in the center.

J. W. Brown: I would like to ask Professor Richards if he tried carbon also.

Mr. Richards: Yes, we tried amorphous carbon cut out of four-inch square electrode, made by the National Carbon Company.

Mr. Lidbury: Would Professor Richards publish those figures?

Mr. Richards: I would be glad to make an abstract of those figures and publish them in connection with the paper. They form a subject of a thesis of one of our students, and I will get permission of the University to publish the results. It was not our intention to publish them until further tests had been made, so the results will have to be taken as provisional values only.

Mr. Hering: In connection with Professor Richards' experiment, I want to call attention to one thing which I mentioned in the paper, but I did not dwell on in abstracting it. Judging from the experience I had in the other test, which is very much allied to this one, it is of extreme importance to wait until the stable state is reached, otherwise you will get all sorts of absurd results, which are not only not approximate, but even absolutely wrong. As long as heat is accumulating in the apparatus you are crediting it to the flow of heat, and that may cause very large errors.

Mr. F. T. Snyder: I would like to call attention to the work that was done by the engineering experimental station of the University of Illinois, on the flow of heat through fire clay at high temperature, as published in Bulletin 36. The difficulty in all of this work is in getting a test piece which is homogenous and which the fire clay people can make. The method used at the University of Illinois was based entirely upon the development of a practical test piece. The test piece they adopted was a hollow cylinder; the heating consisted of a coil through the center. The heat flow was measured as it came out through the cylinder radially at the center section. The temperature was measured by pyrometers put in through holes parallel with the axis of the test cylinder. This cylinder was surrounded by another insulating cylinder. The flow of energy was taken by measuring the potential drop for a short section of the heating coil in the center. It was found for a distance of six or seven centimeters that the flow through the center was practically radial. This work was carried up to about a thousand degrees, so that it gives us practical figures on the ordinary fire clays. They found what Mr. Hering speaks of, the necessity for having the conditions uniform and for that reason a storage battery was used. But even then considerable difficulty was experienced in keeping the heat steady.

W. S. Landis (*Communicated*): In mid-winter, 1909-10, Professor Richards assigned as a thesis title, "Heat Losses through Electrodes of Electric Furnaces," to one of his senior students, Mr. F. R. Kemmer. The mathematics of the subject was quite thoroughly worked up and some attempts were made to determine some of the constants required in the various formulæ. For determining the heat conductivity the method proposed by Mr. Hering in his paper, "A New Method of Measuring Mean Thermal and Electrical Conductivities of Furnace Electrodes"[1] was attempted, but through lack of facilities in our laboratory had to be abandoned before completion. I then suggested to Mr. Kemmer that he try the method proposed by Peclet,[2] that is the use of hollow spheres, as permitting the use of electrode material such as would go into the regular electric furnace. This method is identical with that proposed by Mr.

[1] These Transactions **16**, 317 (1909).
[2] Peclet. Traite de la Chaleur, **1**, 385. Paris, (1860). *Ibid.*, **3**, 453 (1861).

Hering in this paper except that Peclet used either vapor or liquids for supplying the steady flow of heat to his sphere, the heat transfer from vapors being easily measured from the measured amount of condensation. He even used a crude form of thermo-couple for determining the outside temperature of his sphere.

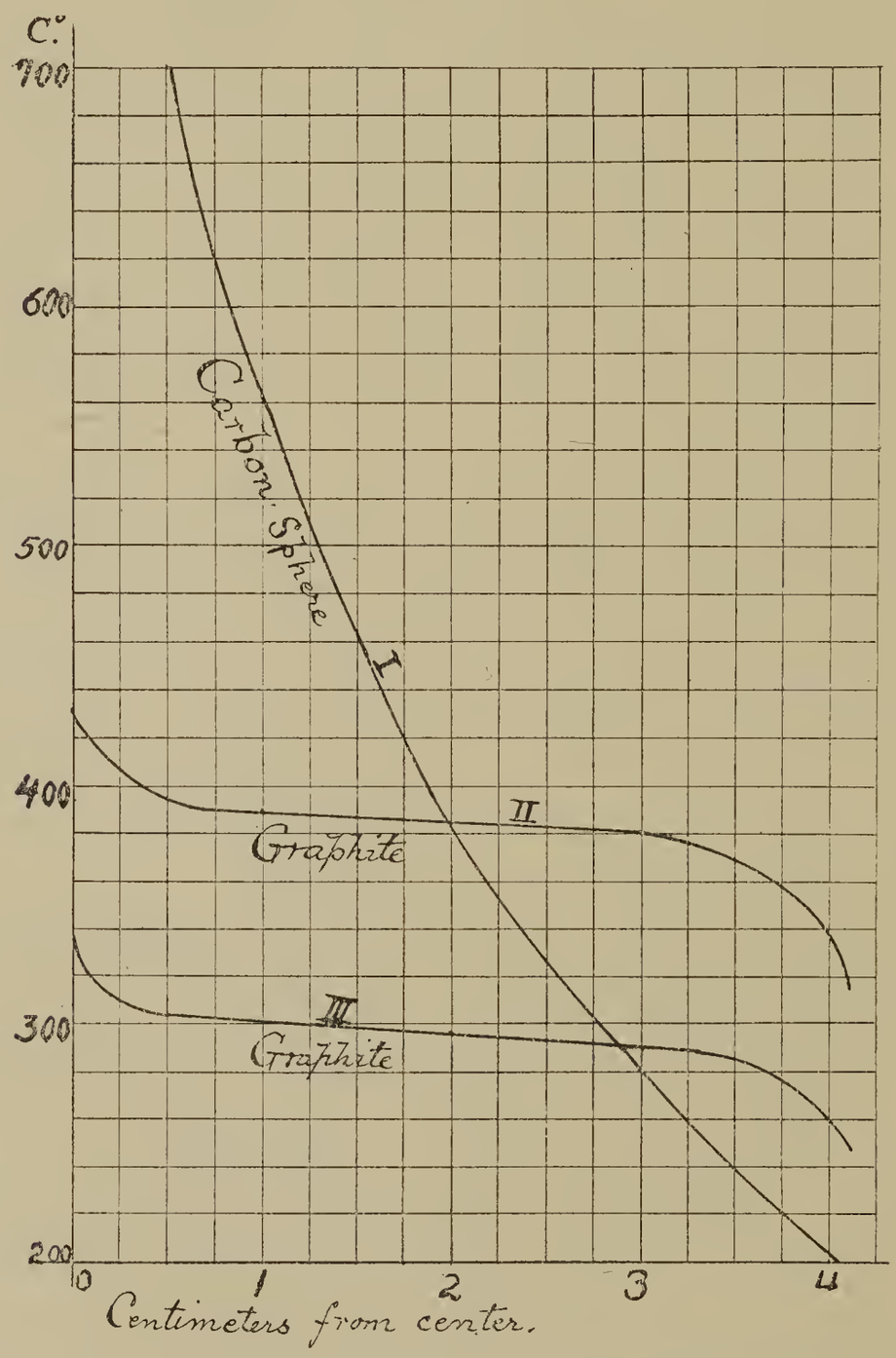
The formulas for calculating the heat conductivity as given by Peclet are different from those of Mr. Hering, in that they are expressed in the form of a differential equation only, with directions as to their solution for each particular case. I tried this method some years ago for determining the constants of various refractory materials, but with success only in the case of materials giving a steep heat gradient, the flatter the gradient the less satisfactory the results. For this latter class of materials the spheres were too small. Mr. Kemmer seems to have arrived at this same conclusion.

In our laboratory we turned out a sphere of graphite and ground to a templet a sphere of carbon, each four inches (10 cm.) in diameter. The graphite sphere was made from a 4.5 inch (11 cm.) round Acheson electrode, and the carbon sphere from a piece of a 4 x 4 x 36 inch (10 x 10 x 90 cm.) electrode made about 1905 by the National Carbon Company. A quarter inch (6 mm.) hole was bored diametrically through each sphere, and at right angles to this another hole one-eighth inch (3 mm.) was bored almost through to the diametrical hole.

The diametrical hole was lined with thin-walled glass tubing for insulating purposes and through the tubing were run two carbon pencils between the ends of which an arc could be sprung. Good electrical contacts could be obtained by plating fast the copper conductors. A nickel-iron thermo-couple was constructed of No. 30 wires and connected to a millivoltmeter of 900 ohms resistance. Through the smaller radial hole temperatures at various distances from the center of the sphere could be measured, the junction of the thermo-couple being protected from direct radiation by the thin shell of material left at the center of the sphere. The spheres were suspended from a stirrup of three No. 30 wires.

The manipulation was very simple; an arc was sprung in the center of the sphere and after one and a half to two hours, when

a steady state had been reached, as evidenced by no further rise of temperature measured at any one section, the thermal gradient was measured, the power input being kept as steady as possible, —a feature giving but little trouble after the long previous heating. These thermal gradients (in each case the averages only being plotted) are given in the curves shown.



Curve I is the thermal gradient for the carbon sphere. Energy 175 watts, ordinates °C, abscissas distances from center, in cm.

Curve II, for graphite, energy input 346 watts.

Curve III, for graphite, energy input 256 watts.

From these gradients were calculated the following values for thermal conductivity.

CARBON		GRAPHITE	
Temperature ° C.	Conductivity CGS Units.	° C. Temperature	Conductivity CGS Units.
		256 Watts.	
280	0.00420	280	0.085
385	0.00667	295	0.198
560	0.02200	302	0.995
		346 Watts.	
		380	0.187
		386	0.435
		390	2.18

The result on carbon as calculated on the inside shell 0.022 is uncertain. Those on graphite are all subject to error due to the high heat conductivity, making the gradient very flat, so that small temperature errors made much greater errors in the final conductivities. Had no one called for this data it would not have been published until some kind friend in the electric furnace business could have been prevailed upon to send us a stub end of say a twelve-inch electrode from which a larger sphere could have been cut, and so have eliminated some of the errors. The first two results on carbon are believed to be good determinations.

One should not compare these results with those obtained by Mr. Hering,[3] because his results were obtained on small dense rods and not on large commercial electrodes such as we used. Checks are visible in our material, and while I have at hand no direct determination of the *apparent* density of Mr. Hering's material, I believe it to have been considerable higher than that of the material used by Mr. Kemmer; at least I have noted very considerable differences between the density of ordinary three-eighth inch rods and the material we used.

Carl Hering (*Communicated*): Owing to the fact that the communicated discussion of Prof. Landis was not sent to me for reply until this volume was nearly ready for the press, I cannot reply in detail. Moreover, the page references to the works of Peclet are incorrect, and this entailed a considerable loss of time in searching for what was meant.

Prof. Landis attributes to Peclet the method which he suggested to Mr. Kemmer, and which he then shows is the same as

[3] These Transactions **17**, 166 (1910).

described in my paper, except that I certainly did not recommend using the arc. Had Peclet described that same method in 1860, as Prof. Landis intimates, it would have been the duty of the papers committee to have declined my paper on the ground of plagiarism, Anyone who has read that distinguished physicist's interesting account of his experiments and his frank and honest statements of failures to get accurate and concordant results would, I think, admit that Peclet would have been delighted to have had the great advantages of using electric heat and the simple, accurate, modern methods of measuring it. His chief troubles were in the correct measurement of the flow of heat. That he would have suggested and used electric heat, had he made his determinations today, is not doubted. That he did not describe the method used by Mr. Kemmer, and that he would have considered it very crude and inaccurate, is evident to anyone who will read his conscientious account of his researches. He suggested and used the hollow sphere (p. 397, Vol. I, not 385, same edition), but only in connection with the older and well-known cooling method, in which there can, of course, never be a constant flow of heat; the difficulty, in fact, was the proper calculation of a gradually diminishing flow of heat. He also suggested the hollow cylinder (p. 399, but seems to have suggested no method of correcting for the losses in the ends) in connection with a constant flow, but acknowledged (p. 455, Vol. III) that "it presents many difficulties and uncertainties," and he decides to fall back to his favorite cooling method. Again, p. 466, Vol. III, in comparing the two methods, he refers with preference to the cooling method as one "which gives rise to no uncertainties." Moreover, Prof. Landis would have found (p. 173, Vol. III) that Peclet himself clearly disapproved using the method of constant flow when testing good conductors; yet this is the very test which Prof. Landis recommended to Mr. Kemmer as Peclet's methods. That Peclet did not claim "the heat transfer from vapors to be easily measured from the measured amount of condensation," as Prof. Landis claims, is shown on p. 455, Vol. III, where Peclet says that the steam is too apt to contain condensed water. Peclet's conscientious criticism of his own work is a good lesson to those who publish crude results with a cloak of accuracy. Lastly,

nowhere in my paper did I claim that the individual elements of the method were new. I did not then know of Peclet's sphere or I should have mentioned his tests; I am therefore pleased to do so now. The chief object of this paper was not only to give a description of a method, but to give the formulas in sample form and in modern terms for direct use, and to show how the leakage for a cylinder could be corrected, and to discuss other details. None of the latter were anticipated by Peclet.

That Peclet's formulas are different from those I used is due to the fact that most of them applied to or involved the cooling method, which is radically different in principle. Those which he gives for the constant flow method would, I think, reduce to the simplified form that I used.

I call Prof. Landis' attention to the fact that a "steep heat gradient" is not at all limited to poor conductors. In one of my tests I obtained an extremely steep heat gradient (about 1000° C. to 100°) in a few inches of a thick bar of copper, one of the best heat conductors known. Like with electricity, it merely requires a greater flow to produce it.

That Prof. Landis' thermocouple was "protected from direct radiation by the thin shell of material left at the center of the sphere" seems entirely unjustified. This thin shell must have been at a dazzling white heat if a 346-watt arc was maintained for two hours within ⅛ inch of that thin shell. Hence, in my opinion, this assumption alone involved a serious error.

That an arc of 346 watts should be maintained very simply for several hours between carbon rods of less than ¼ inch diameter in a confined space as small as a large pea, at the center of a sphere, and have all this energy pass thru the sphere as heat, as it is supposed to do theoretically, would seem to be a rather remarkable achievement. In an arc a part of the electric energy is consumed in vaporizing carbon, and therefore is not set free as sensible heat, altho he evidently assumes it to be heat in his calculations. It becomes heat only when this carbon condenses again. If it condenses, where did this two hours' consumption of carbon of a 346-watt arc condense in this pea-sized aperture? If it escaped, as it probably did in part thru the not closely fitting glass tubes, its energy was not

correctly chargeable to the flow thru the sphere. If it was in part burned by a leakage of air, which is also probable, the heat of combustion was added to the flow, and this would cause another error. The voltage of the arc was presumably about 40; hence the current must have been 8.6 amperes, and as this flowed thru slender encased carbon rods of considerably less than ¼ inch diameter, it must have heated them quite hot; and this heat, which is theoretically assumed to be set free in the center of the sphere, starts its journey in an entirely different place.

The arc must have been extremely short and remarkably docile to be so easily kept steady and not to jump for two whole hours to the surrounding good conductor of graphite, less than ⅛ inch from its center and probably thickly covered with condensed carbon vapor, if the graphite chilled the products as he says it did. Before claiming it was an arc, one should be sure the carbon did not condense and that the interior was not really a resistance furnace, and therefore was not generating heat thruout the greater part of the sphere, for if it did, the regular formulas would, of course, no longer hold good.

He blames the failure of his test of graphite on the smallness of the sphere, and was waiting to receive a gift of a 12-inch one. The wall thickness of his sphere was 7 times the interior diameter; in a 12-inch sphere it would be 23 times. A simple calculation would have shown him that there would be but a very small gain of thermal resistance in the large sphere over the small one,[1] because the cross-section increases so rapidly.

His curves II and III for graphite began at a few hundred degrees. But if there really was an arc, the initial temperature must have been about 3500°. When measurements give such a result, I should assume that nature was trying her best to tell me that something was "out of gear."

The value for carbon which he cast out, namely, 0.022, is, in my opinion, probably the nearest to the true one. He gives no reasons for throwing it out, except apparently that it did not agree with the two others.

But even assuming an accurate determination by this method, it could not have been applied to the now well-known formulas

[1] Heat Conductances Through Walls of Furnaces. These Transactions **14**, *222*.

for electrodes without involving what Prof. Richards had so steadfastly maintained was a serious error in those formulas, due to what he then considered to be a neglect of the temperature coefficient of electrical resistivity. In the determinations which I made for electrode materials, the results of which Prof. Landis claims cannot be compared with his, this alleged large error, is entirely and completely eliminated, and they can therefore be applied directly instead of involving that supposed correction factor which at present no one knows the magnitude of. To argue that this error must be large because there is a large difference between his results and mine would be manifestly unjust until the results were confirmed by a test which gave at least as concordant results and involved as few neglected errors as mine did. It is certainly not just to attempt to discredit results of carefully made determinations because they do not agree with those obtained from a method involving the probably large errors which this one does.

In the early fall of 1908 I suggested to Prof. Richards to make the test with the sphere, which his assistant, Prof. Landis, subsequently carried out, but I certainly did not suggest using the arc; I suggested generating the heat by means of a resistance.

That my determinations are of no use in practice, as alleged by Prof. Landis, because they were made with 5/8-inch electrodes (not 3/8, as he states), I naturally cannot agree with. While it may be true that a small electrode may be denser than a large one, I do not believe that the difference is nearly as great as the errors in his determinations, and those in their application (even if correct) to electrodes in which the temperature coefficient of the electrical resistivity causes a different heat distribution than in his test.[2] Moreover, the loss in an electrode depends on the quotient of the thermal and electrical conductivities; hence if the density of the larger ones is less, it would be likely to affect both conductivities approximately the same, hence would not materially change their ratio. It does not seem just, therefore, to attempt to unconditionally discredit carefully made determinations on this ground. To make a determination of the true electrode constants directly on 12-inch electrodes is a formidable task. Until

[2] Properties and Behavior of Furnace Electrodes. Metal. & Chem. Eng'ing, March, 1910, 128.

this is done, or until more accurate determinations are made, I feel sure mine will give us results which are nearer to those in actual practice than those obtained by Prof. Landis.

A simple calculation made prior to his test would have shown him that he could not expect very good results with the sphere method for such a good conductor as graphite or even carbon. The heat flow required is inconveniently great. It was partly for this reason that I devised and used the other method for good conductors under electrode conditions, and suggested the one in the present paper for non-conductors, under the conditions of simple heat flows. Each of the two tests is then adapted to the very conditions under which the constants are to be subsequently used.

Prof. Landis refers to a "C. G. S. unit" of thermal conductivity, but does not describe it; presumably he means the one based on the calorie per second. It can be shown, however, that to call this unit the C. G. S. unit is an error; a flow of heat is a transmission of energy, and the C. G. S. unit of energy is an erg, and not a calorie. This will be further discussed elsewhere.

Taking Prof. Landis' results for carbon and assuming that there was really an arc, the temperature of which would have been about 3500° C., the mean conductivity figures out to be 0.003 in the same units he used. As he got about 0.004 and 0.007, it would seem to indicate that he could not have had this high temperature, hence had no arc, but merely a resistance, in which case his sphere very probably was a part of the resistance, and the formulas then, of course, do not apply. Whether a determination with such an extremely thick-walled sphere (relatively to the interior) could be correctly applied to bars of uniform cross-section like electrodes is also open to question. For this reason determinations for electrodes had better be made with bars, and those for materials for walls of furnaces with flaring pieces, like thick cylinders, spheres or cubes. This would eliminate an unknown error.

I am indebted to Mr. F. T. Snyder for calling my attention to an important typographical error (a common one in copies made with the typewriter) in the formula for the furnace walls of a rectangular furnace, in my paper on "Heat Conductances through Walls of Furnaces," published in Vol. XIV, of these transactions,

p. 218, formula (4) and reproduced in the present paper near the end, numbered (6) where it is now correctly given. In the former publication the letter "l" occurring twice should be the numeral "1." This changes nothing in the deductions from that formula in that earlier paper, as these were made from the correct formula.

Attention is also called to the fact that the simpler formula (4) in the present paper, given for spheres, is also strictly correct for any rectangular furnace walls and not only for cubical furnaces, as was stated in the earlier paper.

A paper read at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, Ill., October 13, 1910, President W. H. Walker in the Chair.

THE FLOW OF HEAT THROUGH FURNACE WALLS.

By F. T. Snyder.

In the practical design of commercial electric furnaces, two questions have to be regularly answered with regard to the wall material: 1. What profit can be earned on the extra investment by making the wall thicker? 2. Will the materials used melt or change character at the temperatures they are subjected to? The second of these is the more important, as, unless the furnace maintains its mechanical structure for some considerable time, there is usually no profit of any sort. With a furnace that has the same wall material from inside to outside, the requirement is obvious: The material has to be able to stand the temperature needed inside the furnace to do the work the furnace is used for. Most commercial furnaces, however, even in quite small sizes, have walls of composite construction. Sometimes two, but more often three and four, layers of different materials are used. Next to the heat we use the material we have to; outside of that we use the materials we want to. With such composite walls the practical question in design is: What is going to be the temperature of the inside of each layer of the wall, and is that above or below the safe working temperature of the material of that layer? The following is a method of determining these layer temperatures. This method is not as scientific or as mathematical as it might be, as it was developed to meet the needs of active commercial furnace design, and a similar plea may be made for the unit of flow used—temperature drop in degrees Centigrade per inch of thickness, per kilowatt, per square foot. The constituent units are the actual ones in which the data comes to the designer; the furnace drawings give dimensions in feet and inches. American refractories are made in inch dimensions, and the pyrometers usually available are calibrated in Centigrade degrees. The simple plan is to make the constants fit the units

used, and also give results in units that can go on shop and material requisitions without transformation.

Heat is delivered to the inside of the furnace wall in two ways, by radiation, and by convection. It is carried through the wall material by conduction. If the wall is made up of layers, the heat is transferred from one layer to the next by radiation. It is given out on the outside of the furnace in two ways, by radiation and convection. It is the same amount of heat all the way through. The same number of kilowatts that are given to the wall inside by the sum of the radiation and convection there are carried through each layer of the wall, across each joint between the layers, and are given out as the sum of the radiation and convection from the outside of the furnace. As the area of the layers gets larger toward the outside of the furnace, the kilowatts per square foot decrease, but the total kilowatts of heat flow is the same.

The heat given out from the outside of a furnace to the surrounding air by radiation and convection can be calculated for both for any temperature of the furnace surface. The results for the radiation and the convection for each temperature can then be added together and the total heat flow for that temperature expressed in kilowatts per square foot. It is the difference between the temperature of the furnace surface and the temperature of the air that determines this total heat flow. In practice, an annual average temperature of the air is taken at 20° C., and the flow results given in terms of the actual temperature of the furnace surface only. This temperature of the furnace surface alone gives the heat flow through that surface, regardless of the conditions back of the surface or in the furnace. Care should be taken that the actual temperature of the surface is used, and not that of the air next to it. The best plan is to place a thermocouple end on against the surface and protect it from the air by an asbestos sleeve. Anything put over the surface to protect the couple, blankets the surface and raises its temperature.

The radiation from the surface is taken as varying with the difference between the fourth powers of the absolute temperatures of the surface and the air, multiplied by a constant to reduce the results to kilowatts of heat flow per square foot. This constant varies with the material of the surface and its condition.

The convection from the surface is affected by two factors, the transfer resistance of the flow of heat from the surface to the air, and the movement of the heated air away from the surface. The velocity of this movement is in turn determined by the temperature of the surface. Strictly this velocity is also affected by the shape and position of the surface, but practically it has been found, from measuring the velocity of the air for different points on the bottom, sides and top of a number of commercial electric furnaces and plotting it against the temperatures of the surface for the same points, that this velocity can be expressed as a simple function of the difference between the temperature of the surface and the air. The transfer resistance from the surface to the air for each velocity is determined from the empirical formula of Richards. Inside the furnace, for temperatures of 1000° C. and upwards, the temperature difference becomes so small for practical rates of heat flow that the convection is negligible.

For the flow of heat through the wall material, an experimental constant is determined giving the temperature drop in degrees C. through one inch of thickness of the material for a heat flow of one kilowatt per square foot. This constant varies for any material with the temperature range, and should be used only for the range for which it is determined. If not available for a desired range, it may be approximated from the constant of a known range by varying the known constant inversely as the absolute temperatures of the means of the two ranges. If the constant is known for two ranges starting from the same lower point, it can be calculated for the range between the maximum temperature for the two ranges by Hering's formula.

$$x = \frac{KT - kt}{T - t}$$

X = Calories per cm.^{3} for range T — t
K = " " " " " T
k = " " " " " t
T = Maximum temperature range T
t = " " " t

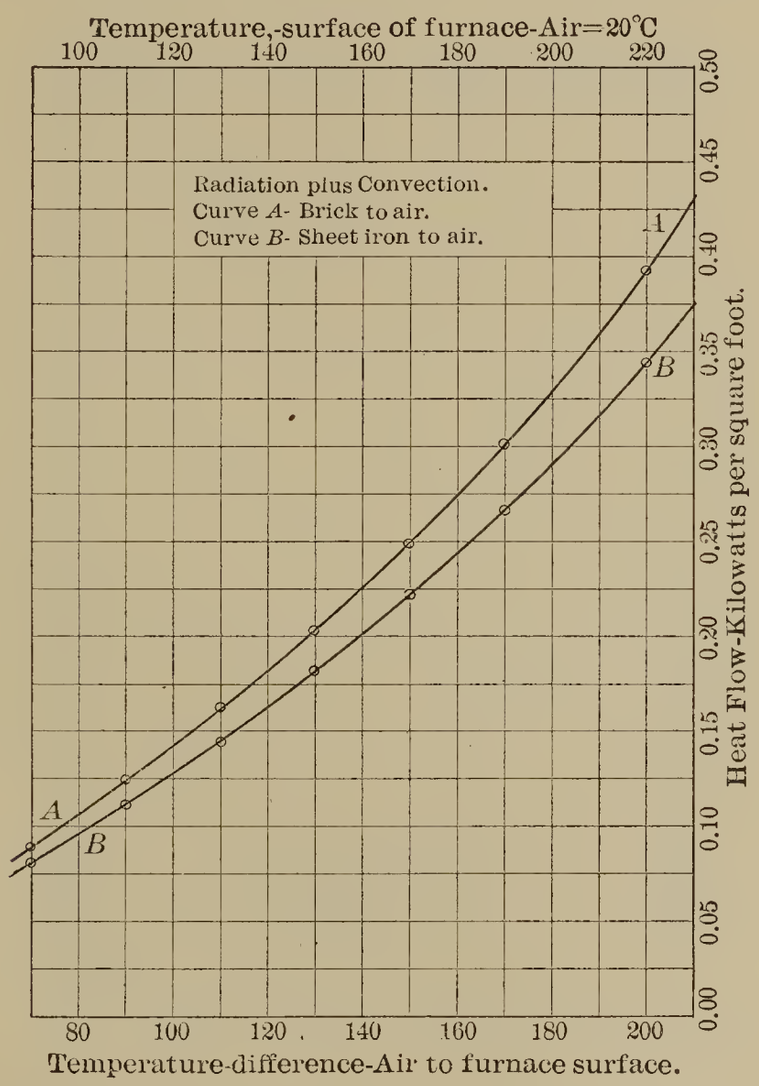
In taking the dimensions of the flow surface, it is usually practical to use the arithmetical mean of the area of the inside

and the outside, but if the thickness is considerable with reference to the other dimensions, it is necessary to use the geometric mean area, or correct the arithmetical mean by Hering's factor.

The resistance to the transfer of the heat from one layer of material to the next, the contact resistance, is determined from an experimental constant giving the difference in degrees C. between the fourth powers of the absolute temperatures of the opposing surfaces for a heat flow of one kilowatt per square foot. This constant should be used near the temperature for which it is determined, owing to the change that occurs in the radiation power of the surface with change of physical structure, and, of course, varies for each material. By adding this constant to the fourth power of the absolute temperature of the cooler side of the contact, the fourth power of the absolute temperature of the hotter side is obtained, and the difference of the temperatures of the hot and cold sides gives the temperature drop across the contact. If the flow differs from one kilowatt per square foot, the constant varies in proportion. The drop across the contact varies not only with the material, but also for the same material with the temperature at which it takes place; it is less at higher temperatures. In this way it is analogous to the flow of energy through a condenser with alternating current; the voltage drop for a given current flow is less as the frequency increases.

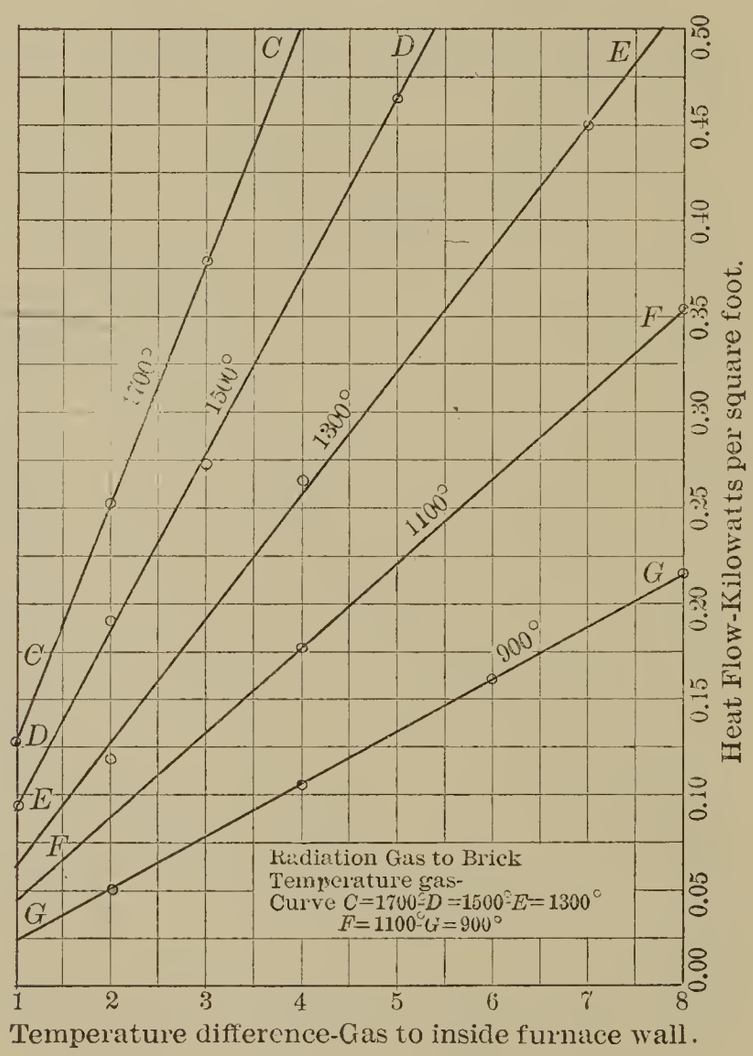
For practical use a set of curves are calculated giving the temperature drops for the common furnace materials and conditions under the different practical rates of heat flow. It is found simpler and quicker to assume a proposed furnace wall as to materials and dimensions, and then calculate the temperature distribution, than it is to assume the temperature distributions and try to calculate the dimensions. In doing the former, the temperature of the air is taken as a start, and the desired rate of heat flow in kilowatts per square foot assumed. The curve for the proper material gives the temperature of the furnace surface necessary to make this flow. The temperature rise through the outside layer of the wall is obtained by multiplying the constant for the material by the thickness, the rate of flow being corrected for the change in mean area. This rise, added to the surface temperature, gives the temperature of the inside of the outside layer of the wall. From the transfer curve for the given rate of

flow is obtained the rise in temperature necessary at the temperature of the cooler side of the contact to force the desired flow across the contact between the layers, the flow per square foot being corrected to correspond with the area of contact between the layers. This rise, added to the temperature of the inside of the outside layer, gives the temperature of the outside of the inner layer. The rise through the inner layer is determined as was the rise through the outer layer, again correcting



the rate of flow to the mean area of the layer. This rise, added to the temperature of the outside of the inner layer, gives the temperature of the inside of the inner layer. If there are intermediate layers, the rise of temperature through each and the contacts between are determined in the same way, using for each material its appropriate constant for the temperature range it carries. From the temperature of the inside of the inner layer, the rise of temperature to the gases inside the furnace is taken

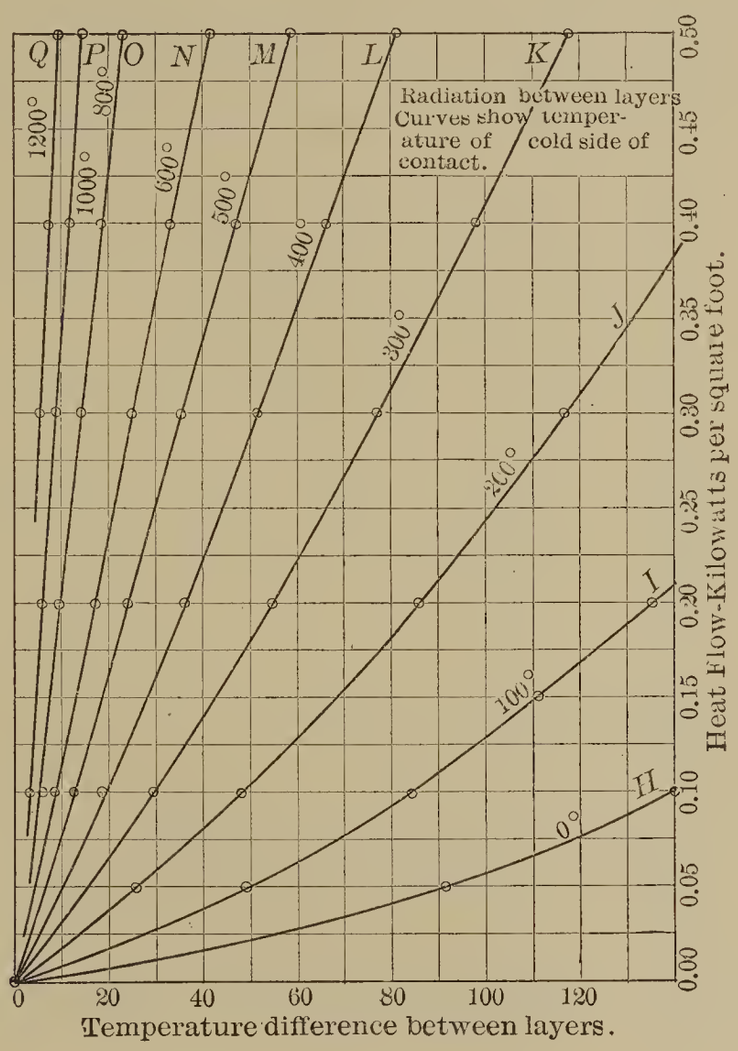
from the curve for the rate of flow, corrected to correspond with the inside area. This added to the temperature of the inside of the wall, gives the temperature of the contents of the furnace. It may happen that the temperature of the furnace contents determined in this way is not that desired for the work the furnace has to do. It is then necessary to repeat the calculation, using a more likely rate of flow, until the assumed rate of flow gives the necessary temperature in the furnace contents. When this is



reached, an examination of the temperatures of the inside of each layer will show whether the material of that layer is safe against physical change.

The material of the inside layer of the furnace wall and its thickness is usually determined without much choice by the chemical and heat conditions in the furnace. It then becomes desirable to determine if there is a profit in adding additional heat insulating material on the outside. If the interest and depreciation due to

adding this extra wall material are less than the value of the heat flow save, the difference is profit. Adding more material changes the heat flow conditions in the material already in the wall. The simplest plan is to make a complete calculation for the heat flow conditions both with and without the extra wall material, and also to make a complete determination of the furnace cost both with and without the additional layer. The addition of an extra layer not only adds the cost of the material of the layer,



but it also increases the cost of the structural parts of the furnace. In adopting a rate of interest on the added cost for material and furnace parts of the extra layer, it should be kept in mind that the earning rate of electric furnace investments is much above the current earnings of the average manufacturing installation. In determining the cost of the extra heat loss without the additional layer, it should be kept in mind that the loss goes on as long as the furnace is hot, whether the electricity is flowing or not. That is, the time between heats has also to be counted in.

Curves A and B give the sum of the radiation and convection factors for different rates of flow in kilowatts per square foot, for different temperatures of the outside furnace surface. Curves C to G give the radiation temperature differences for different rates of flow in kilowatts per square foot, for different temperatures of the furnace contents. At these temperature differences the convection factor is negligible. Curves H to Q give the contact differences for different rates of flow in kilowatts per square foot, for different temperatures of the cooler side of the contact. The radiation factor of these curves is calculated from Stefan's law and Peclet's constants, transformed to the units used.

$$R = a\ (T^4 - t^4)$$

R = Kilowatts per square foot.
T = Temperature of hot material.
t = " " cold "
a = $0.0033 \div 10^9$ for ordinary sheet iron.
a = $0.0042 \div 10^9$ " brick and slag.

The convection factors for these curves are calculated from Richards' formula, transformed to the units used.

$$C = b\ (T - t)\ (2 + 5.5\sqrt{v})$$

C = Kilowatts per square foot.
T = Temperature of furnace surface.
t = " " air.
b = 0.00011 for sheet iron furnace shell.
b = 0.00015 " brick furnace surface.
v = Velocity of convection currents in feet per second.

The velocity of the convection currents for the outside of electric furnaces is determined from the empirical formula

$$V = 0.022\ (T - t)^{\frac{3}{4}}$$

The table given shows the temperature difference required to force a heat flow of one kilowatt per square foot through one inch of different materials for different temperature ranges. An example is given of the calculation of the temperature distribution through the bottom of a small steel furnace for two rates of heat flow, five and four kilowatts for the whole bottom. It results that the inside temperature required for the 5-kilowatt

flow is 1823°, and for the 4-kilowatt flow, 1472° C. By putting the calculation in this tabular form, the work can be done mentally as rapidly as the figures can be written down.

With regard to the data that have been published of the actual flow through composite walls, allowance should be made for the fact that the water-jacket usually used to absorb the heat for measurement on the outside, changes the regular operating conditions, 1, by cutting off the convection, and, 2, by cooling the outside of the wall below its usual working temperature.

Thermal Conductivity of Refractories.

D = Degrees C required to force a heat flow of one kilowatt per square foot through one inch of thickness of the material.
T = Temperature at hot side of material.
t = " " cold " " "

	t	T	D
Alumina brick	0	700	320
Ashes—wood	0	100	3840
Brick dust—coarse	0	100	1680
Carbon—retort, solid	0	100	45
" electrode	100	400	7.1
" "	100	800	5.2
" "	100	1200	5.0
" "	100	1600	4.5
Carborundum sand	18	98	1300
Cement	0	700	3800
Charcoal	0	100	2960
Clinker—small grains	0	700	600
Coke—powdered	0	100	1480
Copper—metallic	0	30	0.7
Fire brick	0	500	465
" "	0	1000	155
" "	0	1300	105
" " dust	20	98	2300
Graphite—dust	20	100	1630
" electrode	100	400	1.9
" "	100	800	2.1
" "	100	1200	2.3
" "	100	1600	2.5
Infusorial earth	17	98	5000
" "	0	650	1720
Iron—metallic	100	200	4.4
Lime	20	98	2250
Magnesia—brick, dust	20	100	1300
" "	0	1000	92
" calcined, Grecian, granular	20	100	1450
" " Styrian "	20	100	1920
" " light, porous	20	100	4100
Quartz—sand	18	98	1090
Silica brick—burned to 1050 C	0	1000	330
" " " " 1310 C	0	1000	210

CALCULATIONS ON THE BOTTOM OF A SMALL STEEL FURNACE.

	Air	Iron Shell	Magnesia Granular	Magnesia Sintered	Steel Molten	Slag Molten
Thickness, In.	. . .	0.5	12	9	12	2
Deg. per K. W.	. . .	3	600	100	4	100
Diameter,						
Inside, Ft. .	. . .	. . . .	5.5	4	3	
Outside .	. . .	7.5	7.5	5.5	4	
Average	. . .	. . .	6.5	4.75	3.5	3
Area, Average .	. . .	44.2	33.2	17.7	9.6	7.1
Corrected		. . . .	31.6	16.3	8.7	. . . .
Electrode	. . .	0.2	0.2	0.2	0.2	0.2
Effec. . .	44.0	44.0	31.4	16.1	8.5	6.9
K. W., Total .	5	5	5	5	5	5
K. W., Sq. Ft.	0.11	0.11	0.16	0.31	0.59	0.73
Deg. per In. . .	. . .	0.3	95.4	31.1	2.4	72.5
Outside, C. . .	20	105	201	1349	1639	1678
Rise	. . .	. . . .	1145	280	29	145
Inside . . .	. . .	105	1346	1629	1668	1823
Transfer . . .	85	96	3	10	10	
K. W., Total	4	4	4	4	4	4
K. W., Sq. Ft.	0.09	0.09	0.13	0.25	0.47	0.58
Deg., per in. .	. . .	0.3	76.2	24.8	1.9	58
Outside C. . .	20	92	174	1090	1323	1356
Rise	. . .	. . . .	914	223	23	116
Inside	. . .	92	1088	1313	1346	1472
Transfer . , .	72	82	2	10	10	

DISCUSSION.

MR. CARL HERING: Mr. Snyder, in his interesting paper called attention to the drop of temperature between the gases at the interior of the furnace and the wall. That drop is sometimes of extreme importance. I suppose in many cases it can be neglected, but there are cases in which it cannot. As an illustration I cite a case, which perhaps is not as well known as it ought to be. A postage stamp can be pasted on the outside of a tube of a steam boiler against which the red hot flames are playing, and the postage stamp will not be charred. This means that on the outside of the boiler tube between the gases and the metal

there is an enormous drop in temperature. There is, therefore, a very steep heat gradient just on the outside of those tubes. The well known experiment of boiling water in a paper cup over a Bunsen flame, is another illustration.

This heat gradient may sometimes be used as a heat insulator, but it is rather an expensive one, because it means that the steep heat gradient is due to a rapid flow of heat.

To give an illustration of what this gradient means, I have investigated it and have found a way to overcome it, so that I could get at least five times the evaporation of water in a vessel. That is, when this insulating film is broken down, the same flame will evaporate about five times as much water as without the device for breaking down that film.

Mr. Snyder also called attention to the heat resistance of a joint. I think that is a very important thing and which someone ought to study and take up and measure. The heat insulation of a joint is very great. We had occasion to see that our last meeting when we visited the Heroult furnace, at the Firth-Stirling Steel Works. I called attention to it at that time. The electrodes projected down into the furnace, and it so happened that just above the furnace there was a joint where one piece of an electrode was screwed on to the next one. I noticed that just up to that joint the electrode was red hot while above it it was black, showing an extremely great heat gradient right across that joint.

Mr. Snyder: I happen to have another bulletin of the experimental station of the University of Illinois, giving the actual figures on the drop on boiler tubes. I might say in regard to what Mr. Hering said that the transfer drop between layers is an important thing at low temperatures, but at high temperature it drops down to three or four degrees centigrade.

Dr. Richards: I think it is extremely important for electric furnace manufacturers particularly, to study the question of the amount of heat transferred through the furnace walls. If they are experimenting with a given thickness of wall with a given furnace, there is one particular which it is important to bear in mind. Given an electric furnace with a wall of a given thickness, and experimenting with different materials in the walls to find

the one which conducts the least heat from the furnace, you have a very good way of comparing the different materials by measuring the temperature of the outside of the furnace shell. The total heat loss from the furnace will vary with the temperature of its outside. I found a very convenient means of doing this by taking an iron-nickel thermo-couple, and holding the junction against the furnace wall. In that way you can measure temperatures up to 500° C. With a given external surface, the higher the temperature outside, the more heat you are losing; and the more efficient the heat insulation the lower the outside wall temperature will be. A still further improvement to be made on electric furnaces is to reduce as far as possible, for a given thickness of wall and given material in the wall, the amount of radiation and convection losses to the air outside. We all know that a rough surface radiates heat faster than a smooth surface and that a dark surface radiates it faster than a light one, so that by modification of the outside of the furnace it is frequently possible to reduce the amount of heat that is being radiated and lost from the outside of the furnace. In that case, given the wall of fixed material and varying the conditions by experimenting with the outside shell of the furnace, the hotter the outside shell is by the temperature in measurement, the more economically the furnace is working. This is true because the higher the external temperature the less the heat gradient from the inside to the outside and, therefore, the less heat is being taken out of the furnace. When you are experimenting on the outside surface of the furnace, to diminish the losses, the hotter the ouside surface of the furnace is, the less heat is being lost from the inside, assuming the walls themselves to be unchanged.

Mr. Frary: I would like to ask what is the nature of this film on the surface, whether is is simply the iron oxide from the oxidization of the iron or whether it includes what we might call dead air mechanically held in place there by the iron oxide and not included in the circulating air.

Mr. Snyder: You mean in regard to the water tubes? There is no film there at all. There is simply the temperature drop.

Mr. Frary: Professor Hering spoke as though there was material.

Mr. Snyder: No, it is simply a contact resistance. There is one thing to note about the temperature drop through this resistance; it varies, not only with the flow of heat but with the temperature at which the flow takes place. It is similar to the transfer of electric energy through a condensor. The amount of energy which goes through a condensor is a function not only of the voltage, but also of the frequency. In the same way these contact temperature drops are function of the temperature, that is, 10 degrees drop at one temeperature will produce a very much greater flow than 10 degrees drop at a lower temperature, —they change quite a good deal. A tenth of a kilowatt flow requires two or three degrees drop at a thousand degrees and about one hundred degrees drop for the same flow per square foot at a hundred degrees.

Mr. Hering: Concerning what Professor Richards said it seems to me it would be a mistake to judge the loss from a furnace by its ouside temperature alone. It depends just as much on the size of the outside of the furnace as to what the loss would be, so the only way to compare the losses in two furnaces would be to not only measure the temperature, but also the area of their outside surfaces.

Mr. Richards: I made that distinction. I meant to say that for a given thickness of furnace wall, comparing different materials in that same thickness of furnace wall you can measure the temperature of the outside and thus get a comparison of different materials composing a wall of given thickness; and when you are experimenting on changing radiation and convection from the outside, if you reduce the radiating power of the outside surface it banks up the heat there and that makes the outside surface hotter, but reduces the total amount of heat which goes from the outside surface to the air and, therefore, lessens the total loss from the furnace.

Mr. Snyder: I might add to what Professor Richards has just said that it is deceptive to try to figure the economy of a lining from any one factor. The question comes up as to whether adding another row of bricks on the outside is going to earn a profit or not. I have found the only way you can answer that question accurately is to entirely design the furnace with and

without the bricks, as adding the additional bricks not only involves their cost and heat insulating power, but changes the heat flow through all the other layers and also affects the construction cost, so it isn't at all obvious whether it is going to earn a profit or not, unless the furnaces are each entirely designed and the relative costs and radiations determined.

CARL HERING *(Communicated)*: In this paper, Mr. Snyder recommends and uses a peculiar unit or constant in terms of which he makes his calculations. This unit represents the physical property of the material by means of a constant, and takes the place of the usual thermal conductivity; it is different from those more generally used, and as it seems to be a new one, I have investigated it in order to find out what its real meaning is, how it is related to the others, and what advantages, if any, it has over the others. The results are briefly as follows.

In the first part of the paper, he calls it a "unit of flow" of heat, and defines it as the "temperature drop in degrees Centigrade per inch of thickness, per kilowatt, per square foot." This is not clear, because a temperature drop is a different physical thing from a unit flow of heat. Moreover, the word "per" in all such expressions is universally accepted to signify that the first quantity is divided by the second. His new quantity would therefore be equal to temperature divided by the product of length, power and cross-section. No such physical quantity exists, and the indications are that it is not a rational one, as it involves the product of the length and section instead of their ratio.

Later on he defines this new constant as "the temperature drop in degrees C. thru one inch of thickness of the material for a heat flow of one kilowatt per square foot." In this form it can be shown to be a rational quantity, if my understanding of his meaning is correct; it can then be shown that the chief difference between it and the more usual conductivity is that while the latter is the *flow of heat* in watts, under unit conditions (that is, for one inch length, one square inch section and one degree temperature drop), Mr. Snyder's quantity is the *temperature drop* required to produce a given flow thru a given length and section.

In so far as it bases this physical property of the materials on temperature drop, instead of on a flow of heat, it is of interest,

and it remains to be determined, by numerous calculations in practice, which of the two is the more convenient to use.

The second and apparently the new feature, however, which involves a cross-section of a square foot and a flow of a kilowatt, in place of a square inch and a watt, is, in my opinion, decidedly against its favor, and is an undesirable change from uniform practice. The constant thus obtained is 6.94+ times the corresponding one for one square inch and one watt, hence there is not even any small advantage due to a better position of the decimal point. Moreover, electric furnaces are at present not so large that they are measured to the nearest foot and fraction of a foot; they are at present generally measured in inches and fractions of an inch. Hence there is not only no advantage in using square feet instead of square inches, but there is a decided disadvantage, as it generally involves an additional conversion of square inches to square feet.

The use of the kilowatt instead of the watt, being a mere change in the decimal point, is too insignificant a matter to warrant the confusion arising by lack of uniformity in practical calculations and in tables of constants.

I am therefore very decidedly of the opinion that the change to a square foot and to the kilowatt is undesirable. If the change from the use of the conductivity to the use of the temperature drop should prove to be a desirable one, and it may well be so, it would unquestionably be better to adhere to the square inch and the watt. In that case the constant would be the temperature drop per inch of length required to produce a heat flow of one watt thru a section of one square inch.

A further analysis of this quantity shows it to be of the nature of a thermal resistivity instead of a conductivity, hence proportional to the reciprocal of the latter. The numerical constant obtained would be strictly proportional to the resistivity, and in view of the fact that at present we unfortunately have no named unit of thermal resistivity, and are not as familiar with its use as we are with that of its mate, the conductivity, it might prove to be an advantage to use this very useful quantity (resistivity) by expressing and measuring it in terms of temperature drop under unit conditions (1 watt, 1 sq. in. and 1 in.); we are then using only quantities with which we are familiar, and the misti-

ness concerning the use of a new, unnamed quantity then disappears. The analogy in electrical quantities would be to represent electrical resistivities not by the ohms of an inch cube, but by the drop of potential required to cause one ampere to pass thru an inch cube.

When thus used, that is, in terms of the more universal inch cube and watt (instead of Mr. Snyder's inch-square-foot and kilowatt), the numerical values of these constants will be the exact reciprocals of the more familiar conductivity in watts; hence the conversion is a simple one. Being the simple reciprocal, that number would be a true expression of a thermal resistivity in terms of a unit which is the rational one to use because it is the true reciprocal of the conductivity. Hence by this method we would, in fact, be using the rational resistivity unit without knowing it and without the necessity of introducing and naming a new unit. It is readily seen that the temperature drop for one watt flow thru one inch cube must be numerically the same as the resistivity expressed in the reciprocal of the conductivity in watts, just as the volts and the resistivity in ohms would be numerically the same in the electrical analogy mentioned above. It is of interest to notice that a thermal resistivity is correctly and rationally measurable in degrees of temperature, just as a thermal conductivity is correctly and rationally measurable in watts.

To illustrate this result with a simple numerical example, let the thermal conductivity of graphite be 3 in watts for an inch cube. Then the thermal resistivity in terms of the rational unit described above would be the reciprocal of this, namely, 0.333, and this would mean 0.333° C. temperature drop. That is, it would require a temperature drop of 0.333° C. to cause a flow of one watt thru an inch cube. This may be easily checked. Assume a piece having a cross-section of 2 square inches, a length of 4 inches, and let the drop be 100° C. The total conductance then is $3 \times 2 \div 4 = 1.5$; hence the total thermal resistance is $1/1.5 = 0.667$. To have this resistance, the risistivity must be $0.667 \times 2 \div 4 = 0.333$; hence this is the same as above. To furthermore show that this number represents the temperature drop for a flow of one watt thru one inch cube, calculate first the total flow in this piece, namely $3 \times 2 \times 100 \div 4 = 150$ watts, or $150 \div 2 = 75$ watts per square inch section. The tem-

perature drop for 1 inch length is $100 \div 4 = 25°$; hence per watt for 1 inch cube it is $25 \div 75 = 0.333°$ C.; hence this is the same as above.

Concerning another feature in Mr. Snyder's paper, in which he says that trial calculations must be made, I do not see why direct calculations would not be possible. In an article in the Electrochemical and Metallurgical Industry, January 1909, p. 11, I showed how the use of thermal resistances instead of conductances simplified calculations in just such cases, namely, when the flow of heat passes transversely thru layers of different materials, and gave direct results instead of results by trial calculations. With the use of the virtual resistivity unit described above, the calculations of such composite furnace walls should be simpler and more direct than by the use of conductivities, provided, of course, that they are carried out consistently thruout, by calculating the total resistance instead of the total conductance.

In conclusion, I have found in practice that one of the best ways to minimize the troubles due to our unfortunate inheritance which he rightly terms the "misfortune of our English system of measurements,"—is to limit ourselves, at least whenever practicable, to one unit like the inch, and then, if we are not accustomed to dealing with very large or very small numbers, (which, after all, is not as bad as it at first appears) simply move the decimal point, say to represent 1,000 square inches; call them kilo square inches, if we like. This is far simpler than the repeated divisions and multiplications of 12, 144, 1728, etc., necessitated by using feet. My own custom, and one which I would strongly recommend, is to make all involved calculations in the metric system and convert merely the end results into our antiquated inch.

Concerning the conversion of constants, I do not agree with him. It is certainly less trouble to convert centimeters into inches than into feet, unless one has the direct conversion constants, which are not generally available.

If the drops of temperature at joints are themselves functions of the temperatures, I grant him that trial calculations are probably simpler than the direct one would be. I certainly do not favor using involved mathematics or what are termed theoretically precise and accurate methods, when a simple short cut, like

a few trial calculations, are quite sufficiently accurate for practical purposes.

Mr. F. T. Snyder (*Communicated*): In reply to Mr. Hering's communicated discussion, it may be again pointed out that the method described was not intended as a model for anyone, but is the development from regular use in the design of large commercial electric furnaces. Aside from all questions of the desirability of uniform systems of measurements, it represents the units actually found most convenient and time saving by the men who have the work to do, after all the units suggested by Mr. Hering and a number of other units had been tried in various forms and discarded for the units used in the paper. The reason for using square feet instead of square inches is entirely one of convenience. It is the misfortune of our English system of measurement that one is not an even decimal multiple of the other. The radiation area of a furnace can be readily estimated mentally in feet, while dimensions in inches are somewhat unwieldy to handle without pencil and paper. In looking over some designs of the year past, the radiation areas varied from 264 square feet to 680 square feet, numbers that are inconveniently large to handle as square inches.

As to the conversion of constants, that is again the misfortune of the English system of measurements and applies equally to Mr. Hering's proposed inch-cube unit and to the foot-inch unit of the paper. In practice, however, it does not amount to anything, as the conversion is made once for all for each determination and altogether there are only a comparatively few practical furnace wall materials.

The reason why the method of trial approximations is used instead of a direct solution, is that the trial approximations give the result much quicker than the direct solution. The reason for this is that the drop of temperature across the contacts between layers of the furnace wall is a function of the temperature of the contact as well as of the rate of flow. With three or four layers to the wall, as in most commercial electric furnaces, this makes the direct solution so complicated algebraically, that it takes much more time than the method of trial approximations.

Further, in using the trial method, the results come out directly

in temperatures, and frequently after carrying a calculation partly through with certain assumed dimensions of furnace construction, it will be seen that the dimensions adopted ought to be something different, before the calculation is carried all the way through. We have found that the carrying through of the complete algebraic solution for the number of false starts that are usual in practical design is extremely laborious and expensive of time. It is similar to the calculations of slags in smelting. All the metallurgical text books have very pretty methods of algebraically calculating the ratio of the acids and bases, including the coke ashes. Actually, in practical commercial smelting, the slag mixture is figured by a method of trial approximations, in about one-tenth the time the algebraic solution requires.

A paper read by title at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, October 15, 1910, President W. H. Walker in the Chair.

SOME ALLOYS FOR PERMANENT MAGNETS.

By C. F. Burgess and James Aston.

In the investigation of electrolytic iron and its alloys, carried out at the University of Wisconsin, under grant of the Carnegie Institution of Washington, tests were made of the magnetic qualities of all samples. Among these, many showed low permeabilities and high coercive forces suggesting their utility for permanent magnets, rather than as electromagnetic material. Upwards of 100 samples were tested for this feature; all of the bars contained chromium, manganese, molybdenum, nickel and tungsten as binary alloys, or in various combinations together or with other elements.

Much information regarding the best steels and the best treatment for permanent magnets has undoubtedly been accumulated by the manufacturers and users of such material, but is held as a trade secret; and published data along these lines is very meager. Again, such publications deal largely with the study of the critical points of the steels, with the view of determining the proper heat treatment to give them for the best service.

The tests here recorded are for the most part on carbon free alloys. The results are mainly of value, therefore, as indicating the influence of the various elements in inducing the conditions necessary for a good permanent magnet. They were made upon an Esterline permeameter, an apparatus giving directly the flux density in the bar under test for any impressed magnetizing force. It consists of a small dynamo, driven at predetermined constant speed. The test bar forms part of the magnetic circuit of the generator, and can be subjected to magnetizing forces of varying degrees. The flux density in the bar, being directly proportional to the voltage set up, can be read off on a properly calibrated millivoltmeter.

It is not necessary to make a complete magnetization curve in

testing material for permanent magnets. The desirable feature is to have as high a residual magnetism as possible, or, better, to have a high retentivity after some disturbing factor has tended to destroy the residual magnetism, together with a high coercive force to resist the tendency towards this loss of the magnetic flux. The method of procedure was as follows: The bar was inserted in the permeameter, the magnetizing force, H, was raised to the maximum of 200 and the density, B (MAX), was recorded, H was decreased to zero, and the retentivity, B (RET), noted; next the coercive force, Hc, necessary to reduce the retentivity to zero, was determined. Similar readings were taken for the reverse magnetizing forces, and the average of these positive and negative readings of B (MAX), B (RET) and Hc for each bar was recorded for comparison. In fact, the whole operation is identical with the taking of a hysteresis loop, in which only the few readings noted above were recorded.

The bars were tested as forged, and after water quenching at 1000° C. To prevent oxidation of the samples while heating them for quenching, a barium chloride bath was used. The quenching at 1000° C. may not have brought out the best qualities of some of the bars; but it was deemed the best general treatment, since with so many bars under test, it was impossible in this research to subject each sample to tests for its critical points and special conditions of heating.

In addition to the general test noted above, all bars which showed a fair retentivity and a coercive force above Hc = 30 were subjected to a test for their stability or their ability to hold residual magnetism after shock. For this test the bar was subjected to the maximum magnetizing force of Hc = 200, and the retentivity noted when this magnetizing force was reduced to zero. The bar was then removed from the machine, subjected to the disturbing factor, and the retentivity again recorded after reinserting the sample in the permeameter. The two means commonly employed in practice for seasoning permanent magnets were used, namely, jarring or rapping the bar, and boiling. For the latter treatment, each bar was inserted in a piece of wrought iron pipe, which served as a shield to prevent the mutual influences of the magnetic fields, and boiled in water for three hours.

A large number of comparative trials of the rapping and boiling

treatments showed them to be practically equal in their effect, and because of the simplicity of the former, it has been resorted to in the later tests. However, should the material be very brittle, it would be safer in practice to use the boiling method.

As indicating the efficiency of the rapping treatment, there are noted below the results of successive jarring upon the retentivity or a bar of composition 7Cr 3W 2Mo (7, 3 and 2 being the percentages of the three elements).

H (MAX)	= 200	
B (MAX)	= 11100	
B (RET)	= 7500	
B (RET)	= 4900	(removed and rapped 1)
B (RET)	= 4700	" " " 2
B (RET)	= 4700	" " " 3

As will be seen, but one vigorous rapping is necessary, since this reduces the residual magnetism to a value which is but little changed by further shock.

Only the general summary of the tests are given, since it was not deemed advisable in a paper of this character to include the complete tabulation of the data. In Table I are noted the data of the stability tests which, as mentioned previously, include only those materials best suited for permanent magnets. The alloys are divided into five groups, according to their content of chromium, manganese, molybdenum, nickel and tungsten, either alone with iron, or together with iron and any other elements except the above five; in addition, a sixth miscellaneous group includes materials of various compositions in which more than one of the above five metals are present.

The results as a whole showed a wide variation in the physical and magnetic hardness of the various bars, not only before quenching, but afterwards as well. Also, it appeared that the effect of quenching was varied in its results, with either increase or decrease of coercive force, or with no material alteration. However, it appeared that where marked changes were the result, it was generally with an increase of magnetic hardness.

Chromium. In the chromium group, it appears that this element alone, even in percentages as high as 16.65, does not result in bars of high coercive force suitable for permanent magnets, even after quenching at 900° C. And the coercive force was no higher with large than with small chromium additions.

Table I.

Stability of Permanent Magnets.

H(MAX) = 200.

Bar No.	Composition (The figures give the percentage present.)	As Forged			Quenched at 1000° C		
		B(Ret)	After Rapping		B(Ret)	After Rapping	
			B(Ret)	Hc		B(Ret)	Hc
	CHROMIUM STEELS						
133E	4Cr 0.84Si	15050	. . .	14.9	9000	3500	41.5
133D	5Cr 0.84Si	7500	3300	41.0	9500	4800	41.8
133B	5Cr 1.4Si	15700	. . .	16.2	8800	3900	46.0
160J	5Cr 0.3V	7400	3400	53.0	9000	2700	42.2
160H	5Cr 0.5V	9000	3600	50.5	9100	4200	45.0
160K	5Cr 1V	8400	4100	48.1	9200	4900	49.0
133L	6Cr 0.4Si	15650	. . .	14.9	9600	3700	49.0
133K	6Cr 0.84Si	15300	. . .	13.6	9400	5200	52.3
147Z	6Cr 1.3Si	9200	. . .	16.2	8800	3400	50.0
133F	6Cr 1.68Si	14300	. . .	17.9	8300	3800	50.0
133M	8Cr 1Si	12550	. .	16.2	8700	2400	48.5
111S	10Cr 2Si	10000	. . .	19.2	7100	3600	54.0
155K	10Cr 2Si 0.3V 0.6C	11200	2300	30.5	3000	1600	69.0
137L	10Cr 2Si 2Ti	10850	. . .	16.4	7500	4200	62.0
122E	10Cr 3Si	10800	. .	12.3	7400	3500	47.8
160I	10Cr 0.3V	7500	4000	72.5	7800	3500	58.0
155L	10Cr 0.3V 0.65C	4600	3100	84.6	7200	. . .	91.9
160G	10Cr 0.5V	7000	3600	65.0	. . .	. . .	. . .
163O	10Cr 1V	7600	3500	62.8	8400	4500	54.5
141C	10.3Cr 1V 2Si 0.3C	9500	. . .	20.9	8000	2600	38.0
133N	13Cr 1.8Si	12750	. . .	16.7	7100	4000	62.8
136H	17Cr 1½Si	2100	1100	89.3	4900	2700	85.0
	MANGANESE STEELS						
170D	6Mn	8500	4000	50.0	. . .	. . .	. . .
	MOLYBDENUM STEELS						
160E	4Mo 0.6V	12950	. . .	15.3	10400	2600	33.3
156E	8Mo 0.3V 0.6C	9900	3500	37.8	12000	5000	52.2
160C	10Mo 0.3V 0.4C	13700	. . .	23.7	10400	4900	55.8
163H	10Mo 1V 0.4C	10850	. . .	25.1	9400	5000	53.5
141F	10Mo 1.2C	. . .	. . .	. . .	10100	4000	37.0
	NICKEL STEELS						
160M	10Ni 0.6V	9700	3400	30.8	9700	4000	27.2
146P	10Ni 2Si 1C	6700	3200	58.7	1000	900	58.0
	TUNGSTEN STEELS						
160P	4W 0.4V	8250	. . .	12.4	11300	3300	37.5
163J	4Wo 0.4V 0.5C	11200	3000	34.8	8800	4100	67.5
163D	4W 0.4V 0.6C	10400	2900	33.0	9200	4600	68.2
163K	4W 0.4V 0.8C	8900	2800	32.5	6600	4400	70.6
155X	5W 0.5C	10350	. . .	24.5	12000	5200	52.5
WIC	6W + C (?)	12500	2700	28.0	. . .	. . .	
163E	7W 0.3V 0.6C	10900	3800	38.0	9600	5600	81.0

TABLE I.—*Continued.*

Stability of Permanent Magnets.

H(MAX) = 200.

Bar No.	Composition (The figures give the percentage present.)	As Forged			Quenched at 1000° C		
		B(Ret)	After Rapping		B(Ret)	After Rapping	
			B(Ret)	Hc		B(Ret)	Hc
	MISCELLANEOUS STEELS						
150C	2Cr 10Mo 0.5C 0.3V . . .	6900	3600	58.0	10700	6300	77.2
155S	10Cr 5Mo	8700	4000	59.0	7300	3600	70.5
155U	2Cr 10W	10100	. . .	23.4	9500	3900	49.0
156F	3Cr 8W	9400	. . .	24.1	9900	4700	47.5
163A	5Cr 2W 0.6C	6900	3800	61.0	7300	2500	55.0
163G	5Cr 5W 0.6C	3400	1700	68.5	6400	4200	85.0
163C	10Cr 2W	7400	4200	71.7	7500	4200	62.0
156K	10Cr 2W 2Si	5800	3200	76.6	. . .		
156J	10Cr 2W 0.6C	4900	3000	89.9	7100	4800	95.0
156H	10Cr 2W 0.3V	6900	3700	66.0	6900	3800	61.4
156I	10Cr 2W 0.3V 0.6C	4300	2500	82.7	7000	3900	91.0
155V	10Cr 10W	5800	3300	80.5	6500	3600	72.7
150B	2Cr 10W 10Mo 0.3V 0.4C	6100	3500	66.5	8400	3700	59.0
150D	2Cr 16W 5Mo 0.3V 0.5C .	5700	3600	64.0	8600	5000	63.5
163B	7Cr 3W 2Mo	7300	4100	82.5	7400	2500	47.5
156G	10Cr 2Mo 2W	7100	4100	78.5	6600	3800	65.8
156M	10Cr 2W 2Mo 0.6C	4300	2500	82.0			. .
156P	10Cr 2W 2Mo 2Si 0.3V . .	8500	1900	31.0	6800	2700	60.0
136M	5Cr 3Mn 4Mo 1Si	10800	5300	64.7	5800	2900	72.2
140Q	5Cr 6Mo 10Mn 10Ni 1C .	10100	4000	38.2	7000	4400	85.3
144Z	2Cr 10Ni	8100	3200	36.9	8200	3300	29.0
154E	5Cr 10Ni	9100	4000	57.7	5400	2900	47.0
154F	7Cr 10Ni	4700	2500	64.0	2000	1100	55.7
154A	10Cr 8Ni	1600	. . .	80.8	800	300	73.5
136V	10Ni 5Mo	9600	2300	36.0	8600	3600	32.0
146Q	10Ni 10Mo 1C	5500	3000	69.7	5500	2800	70.4
146S	10Ni 10Mo 0.5C	8900	4900	61.0	8400	4000	52.0
152Z	10Ni 5W	8400	3100	36.0	8600	2800	29.7
155Y	10Ni 5W	9050	. . .	17.0	10900	4600	38.0
155AB	15Ni 5W	8300	3000	38.5	8000	2300	37.8
156A	1Mn 2Mo	9450	. . . .	27.3	10600	4600	38.5
155P	1Mn 10Mo 0.5C	6900	3600	61.0	11200	5400	57.5
156C	2Mn 5Mo 0.6C . . .	9500	5500	57.2	8400	4700	68.0

A large number of chrome-silicon alloys were tested, and in practically all cases the bars were relatively soft and of low coercive force in the forged condition. The coercive forces in all but two instances were well below 30, and the alloys were thus unsuited in this state for permanent magnets. In these two instances but little change resulted on quenching; but for the other bars, quenching resulted in a marked increase of coercive

force; and with the accompanying relatively high retentivities, these materials were well adapted for permanent magnets. The best alloys seemed to have about a medium chromium content (5 or 6 percent), since then the retentivity was high and the coercive force great enough to ensure stability.

The addition of vanadium also seemed to be very beneficial, although in this case the raw forged bars were especially hard, and the coercive forces were high initially, and suffered but little change in quenching. Here again, the best results seem to be gained with medium chromium content, because of the higher retentivities.

In a few instances, carbon was present, together with vanadium and silicon. The materials showed hardening upon quenching, but the magnetic results were no better than where there was no carbon.

Summarizing, it may be said that the addition of chromium alone to carbonless iron will not result in a material suitable for permanent magnets; but that the further addition of 0.75 to 1 percent of silicon or 0.3 to 0.5 percent of carbon to 5 or 6 percent of chromium is highly beneficial, and gives an alloy very suitable for this class of service.

Manganèse. According to the classification adopted, the only manganese alloys falling in this group were of a series in which manganese alone in varying amounts had been added to the iron. In the raw forged condition, the coercive force increased, with a corresponding decrease of retentivity, for each increase of manganese content, until at 10.41 percent Mn the alloy was non-magnetic. A bar with 10 percent of manganese had the high coercive force of 90.1, but the retentivity was too low for permanent magnets. The most satisfactory bars were two with 4.51 and 6.0 Mn, where the retentivities were fairly high and the coercive forces great enough to insure stability.

But three bars were tested after quenching, and the result was a decrease of coercive force, a peculiarity corroborated by other tests upon this series.

Molybdenum. Of the entire set of results for this series of alloys, only one was magnetically hard in the forged condition; this was a bar of composition 8Mo 0.3V 0.6C, which had the high retentivity of 9200 and the fair coercive force of 39.0. In

the quenched condition, there was practically no change in any of the carbon free alloys. But in four cases where carbon was present, the quenching resulted in physical hardening of the bars, and they became very fine materials for permanent magnets, with exceptionally high retentivities and very good coercive forces. In one case, a bar with 4Mo and 0.6V attained a good coercive force; whether this was due to absorbed carbon is problematical. If the magnetic hardening took place without the aid of carbon, it would indicate that the proper conditions of temperature, etc., might have the same effect on the other molybdenum alloys. This is merely conjecture, however, and the tabulated results showed no hardening effect of vanadium, such as was noted for the chromium alloys.

Nickel. In the binary alloys of nickel and iron, increase of nickel caused a decrease of retentivity and increase of coercive force, until at about 26 percent of nickel the material was non-magnetic. Beyond this percentage, the magnetic properties were restored, the alloys being of rather high permeability and low coercive force. Quenching at 900° C. invariably greatly decreased the coercive forces, so that none of the binary nickel alloys can be considered suitable for permanent magnets in the quenched condition, either because of low coercive force, or because of low retentivity where the coercive force is ample.

The addition of vanadium resulted in increased magnetic hardness, which was again increased by quenching. The most satisfactory bar was one with 10Ni 0.6V, which in the forged condition had a retentivity of 9900 and a coercive force of 32.6; both values were slightly lowered by quenching. One bar with 10Ni 2Si 1C had a fair retentivity of 6800 with a high coercive force of 62.0 in the forged condition; but after quenching it became almost non-magnetic.

The nickel alloys as a whole, therefore, cannot be regarded as satisfactory materials for permanent magnets. In this case, as noted for chromium, the vanadium seems to act as a hardening agent.

Tungsten. Seven binary alloys of tungsten and iron were recorded, with a tungsten content varying from 0.93 to 23.87 percent. In no instance was the coercive force high enough to make them suitable for permanent magnets; and quenching had

but little effect, usually resulting in a decrease of coercive force. For the two alloys where there was an addition of vanadium, one bar, with 4W 0.4V, became, after quenching, an exceptionally good permanent magnet, with a retentivity of 11300 and coercive force of 43.8; on the other hand, another sample, with 7W 0.3V, experienced but slight increase of hardness. A bar with 5W 0.5C became noticeably harder after quenching, with increase of retentivity and coercive force to the high values of 11700 and 59.0. Four other bars were very good for permanent magnets as forged, and there was a marked hardening, due to quenching.

Summarizing, the binary alloys of tungsten and iron are not satisfactory for permanent magnets. The addition of vanadium may be beneficial, and the addition of carbon certainly is. There were in this series some highly satisfactory alloys; of those worthy of particular mention, however, all but one contained carbon.

Miscellaneous. This miscellaneous group included such a large number of combinations of these several self-hardening alloys that a systematic discussion of the results is difficult. Of the 51 bars here grouped, almost two-thirds were good materials for permanent magnets. The effect of quenching was somewhat varied; in 13 instances there was a considerable increase of coercive force, in 30 cases but little change, and in 6 instances a marked decrease. In 4 cases bars which were originally poor became of fair quality after quenching; and in numerous instances the quality of fair materials was greatly improved; in no case, however, has quenching resulted in a bar of fair quality becoming poor material for permanent magnets, although at times the quality was better before quenching than after.

One of the most striking features noted was the detrimental effect of the additions of nickel, with its tendency towards non-magnetic alloys. In all cases where the material was classed as non-magnetic, or where it was worthless for permanent magnets because of very low retentivity, there was a considerable amount of nickel present. Of the 17 bars of poor quality for permanent magnets, 12 had nickel; and of the 5 bars without nickel, the quality was poor not because of a tendency towards being non-magnetic, but because the coercive force was too low. Several bars of nickel with chromium, with molybdenum, or with tungsten, had fair retentivities together with high coercive forces.

The various combinations of chromium with molybdenum or tungsten, either alone or with additions of silicon, vanadium and carbon, gave generally satisfactory results. In fact, it is difficult to point out any preferable combinations of these various self-hardening elements beyond the caution to keep nickel out of the alloy.

Of particular quality may be mentioned the following:

Bar	Composition	B (Ret.)	Hc.	
136M	5Cr 3Mn 4Mo 1St	11350	55.8	As forged
136V	10Ni 5Mo	10150	36.7	As forged
150C	2Cr 10Mo 0.5C 0.3V	10500	78.0	Quenched
155Y	10Ni 5W	10300	35.2	Quenched
156A	1Mn 2Mo	10500	39.6	Quenched
155P	1Mn 10Mo 0.5C	10750	58.4	Quenched

Strange to say, two of these alloys have a high nickel content, but they may be put down as exceptions to the general rule. The values given above indicate a very high standard of material for permanent magnets.

Summarizing, it may be deduced from the above tests that chromium, manganese, molybdenum and tungsten are the important additions in the manufacture of steels for permanent magnets; but the presence of some third element is necessary. While carbon is beneficial, it is possible to obtain highly satisfactory materials either by various combinations of the above four elements or by suitable additions of silicon or vanadium, the latter, in particular, being very desirable. Also, suitable materials may be made which will require quenching, although in this case carbon is most beneficial; or, if desired, equally satisfactory results may be obtained without.

Stability. As mentioned previously in the general discussion of the tests for permanent magnets, a better indication of the value of material for this service is obtained by a stability test which gives the residual magnetism after shock. In our tests the rapping method was used, the details being given above. Those bars were tested which showed a coercive force above 30, either before or after quenching, this being considered the minimum value at which permanence might be expected.

The details are tabulated in Table I, in the same order as used in the general discussion. The figures of interest are those for the retentivity, B (RET), after rapping; they show the

marked decrease of the residual magnetism due to shock, a decrease averaging about 50 percent, but varying according to the coercive force of the material under test.

For purposes of comparison, and for illustrating the above points, the following tables have been prepared. For Table II the data have been taken from general tests, and there are listed those bars having a retentivity above B (RET) = 10,000, and a coercive force exceeding Hc = 30.0, the order being according to the value of B (RET). In Table III, the selections are taken from stability Table I, and are ranked on the basis of the values of B (RET) after rapping.

TABLE II.

Bar	Composition	B (Ret.)	Hc.	
WIC	(6W + (?) C)	13450	30.0	As forged
156E	8Mo 0.3V 0.6C	11750	53.7	Quenched
155X	5W 0.5C	11700	59.0	Quenched
136M	5Cr 3Mn 4Mo 1Si	11350	55.8	As forged
160P	4W 0.4V	11300	43.8	Quenched
163J	4W 0.4V 0.5C	11050	38.0	As forged
155P	1Mn 10Mo 0.5C	10750	58.4	Quenched
155K	10Cr 2Si 0.3V 0.6C	10700	32.9	As forged
163D	4W 0.4V 0.6C	10650	35.5	As forged
150C	2Cr 10Mo 0.5C 0.3V	10500	78.0	Quenched
156A	1Mn 2Mo	10500	39.6	Quenched
163E	7W 0.3V 0.6C	10450	39.4	As forged
160E	4Mo 0.6V	10400	35.0	Quenched
160C	10Mo 0.3V 0.4C	10350	59.8	Quenched
155Y	10Ni 5W	10300	35.2	Quenched
136V	10Ni 5Mo	10150	36.7	As forged
141F	10Mo 1.2C	10000	37.4	Quenched

TABLE III.

Bar	Composition	B (Ret.) After Rapping	Hc.	
150C	2Cr 10Mo 0.3V 0.5C	6300	77.2	Quenched
163E	7W 0.3V 0.6C	5600	81.0	Quenched
156C	2Mn 5Mo 0.6C	5500	57.2	As forged
155P	1Mn 10Mo 0.5C	5400	57.5	Quenched
136M	5Cr 3Mn 4Mo 1Si	5300	64.7	As forged
155X	5W 0.5C	5200	52.5	Quenched
133K	6Cr 0.84Si	5200	52.3	Quenched
150D	2Cr 16W 5Mo 0.3V 0.5C	5000	63.5	Quenched
163H	10Mo 1V 0.4C	5000	53.5	Quenched
156E	8Mo 0.3V 0.6C	5000	52.2	Quenched

As will be seen by comparison of the two tables, there are bars listed in Table III which do not appear in Table II. Another feature is that the order of rank is not the same for those mate-

rials which are noted in both tables. It will be noted, likewise, that some of the alloys which have high rank in Table II are low down in Table III, or do not appear at all, because the coercive forces are not great enough to retain a high residual magnetism after shock. All materials listed in Table III have high coercive forces, about Hc = 50, and it would appear that for permanent magnets to give good service it should reach this value.

As a result of these tests, it appears that for the investigation of materials for permanent magnets, this stability test gives a very satisfactory indication of the quality. In addition, of course, it would be necessary to test the ageing qualities, or the ability to retain this residual magnetism for long periods of time, and under working conditions.

A paper presented at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, October 15, 1910, President W. H. Walker in the Chair.

APPLICATIONS OF ELECTROSTATIC SEPARATION TO ORE DRESSING.

By F. S. MacGregor.

The possibility of utilizing the differences in the electrical conductivity of various minerals by giving a part or all of the particles of ore an electrostatic charge has for several years been recognized as a means of separation, and a large amount of experimenting has been done along this line. The commercial application of the art of electrostatic separation has been tried a number of times within the last decade, but until only within about three years has success attended the efforts.

Two factors contributed to this want of success—a lack of the proper means of continuous electrification, and a practical machine and system of treatment designed to meet the rigorous requirements of mill operation. Recognizing these conditions, the Huff Electrostatic Separator Company, of Boston, has perfected several types of separators and a means of electrification which have been a commercial success from their first installation, and at present the entire concentrating and separating machinery of two plants consists of Huff separators—one located at Platteville, Wisconsin, owned by the American Zinc, Lead and Smelting Company, and the other at Midvale, Utah, owned by the United States Smelting, Refining and Mining Company. Also a plant is being installed in Nevada.

The type of machine is shown in the accompanying illustration, and consists of a series of separating electrodes placed one above the other. The frame is cast-iron, built in sections, with two electrodes to each section, which facilitates easy shipment and also flexibility in the number of treatments which can be given the ore, and which is dependent on its requirements. A three-section machine (the usual type) is six feet high, six feet six inches long, and eighteen inches wide. A feed hopper on the

top distributes the ore across the first electrode, and it passes by gravity to each succeeding one. The mineral particles receive their charge while passing through a concentrated static field formed by two electrodes—one a grounded rotated shaft, and the other an insulated metal rod. The electrostatic charging of the electrodes is accomplished by a special electrical apparatus (using commercial dynamos and transformers), which, with no more than the usual oiling, gives either a continuous and steady potential of several thousand volts, or an intermittent or pulsating charge of great regularity. The potential, or strength of the field, can be altered at will, according to the conductivities of various ores treated. The figure shows the scheme of separa-

FIG. 1. Wet Concentrator and Electrostatic Separating Plant, U. S. Smelting Co., Midvale, Utah

tion, the dotted lines indicating *in general* the path of the conductors and non-conductors.

The separating plant at Platteville was started in March, 1908, and was the first plant to be equipped with Huff separators. Although originally built as an experimental plant, it has been in practically continuous operation since then, and used to separate, without roasting, the iron pyrite from the zinc blende, which occur together in varying proportions in southwestern Wisconsin. The ores are milled in ordinary jigs and the lead and lime rock removed. Owing to the nearness in specific gravity of the blende and pyrite, they are recovered in the jigs as a middlings, containing from 10 to 45 percent zinc, according to the grade of the crude ore, the remaining percentage being iron and the sulphur in combination. Iron above a few percent

interferes with the smelting of the blende, and the function of this plant is to remove this pyrite, making the low-grade ores into high-grade smelting ores.

The plant consists of a wooden, frame building, 9 x 12 meters (30 x 40 feet), and three stories high. On the first floor are the bins for collecting the finished products as they are delivered from the separators. The second and third floors are separator floors, and in the tower is located the screening system. A spur railroad track runs on either side of the mill, one for cars of raw ore, allowing them to be unloaded either directly into the mill

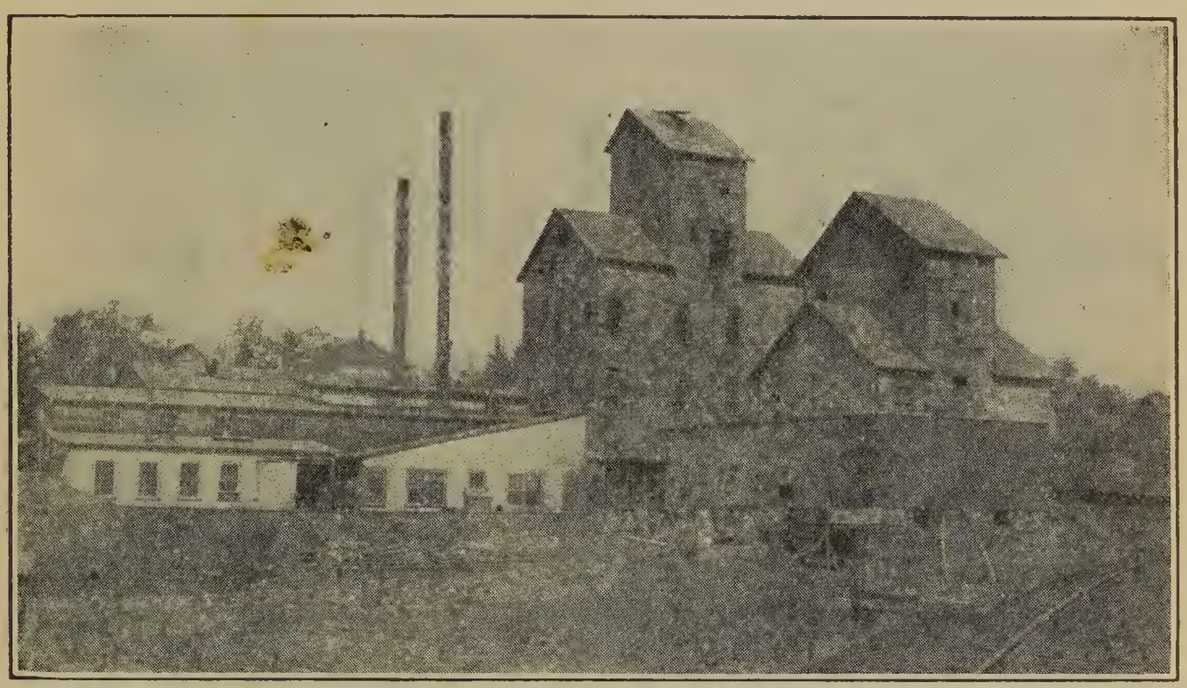


FIG. 2. Electrostatic and Separating Plant, American Zinc Ore Separating Co., Platteville, Wis.

or into storage bins across the track. The other track, which is below the mill level, permits at the same time the loading of empty cars with finished products.

The course of the ore through the plant is shown in the flow sheet, and may be described in detail as follows: It is shoveled into a wheel-barrow in the freight car, wheeled to scales and weighed, then dumped into the feed hopper of the dryer. The top of this hopper is on a level with the car floors to facilitate easy handling of the ore, and at the bottom of this hopper is an adjustable plunger feeder. The dryer is of the cylindrical type, and the shell is 5 meters (16 feet) long and

0.75 meter (30 inches) in diameter, rotating about 4½ r. p. m. Being set at a slight pitch, the ore travels gradually to the discharge end, where it emerges bone-dry. As the separation depends on the difference in conductivity of the minerals, it is necessary that all moisture be removed.

A short drag conveyor carries the dried ore to the foot of a bucket elevator, which raises it to the top of the tower and discharges it into a set of screens. There are four, giving an

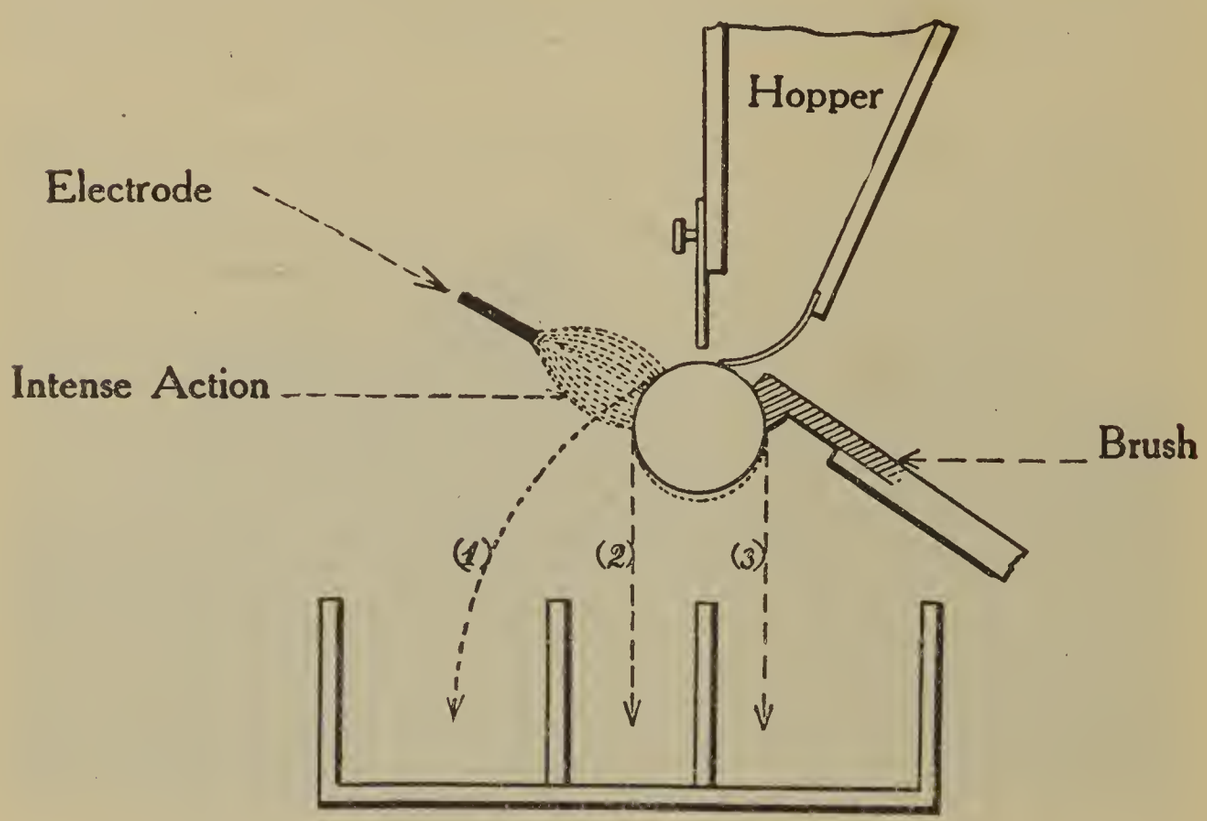


FIG. 3. Section of Electrostatic Separator showing principle of operation.

oversize and four other sizes, called A, B, C and D. In general the sizes are as follows:

A size	.....6 x 5 mesh.	(7 x 8 mm.)
B "	.....10 x 7 "	(4 x 6 ")
C "	.....24 x 20 "	(0.16 x 0.20 ")
D "	.....50 x 50 "	(0.08 x 0.08 ")

The oversize passes through a short trommel to remove any foreign materials, and is spouted to the first floor to a set of rolls, which crush it and deliver it to the boot of the elevator carrying the original feed.

The location of the screens in a tower permits the different sizes to flow by gravity through iron pipe 5 cm. (2 inches)

diameter to the top machine floor. On this floor are located the rougher machines, where the ore is given a rough split, that is, two products are made, one a product higher in zinc than the original feed, and the other higher in iron. Thus, no matter

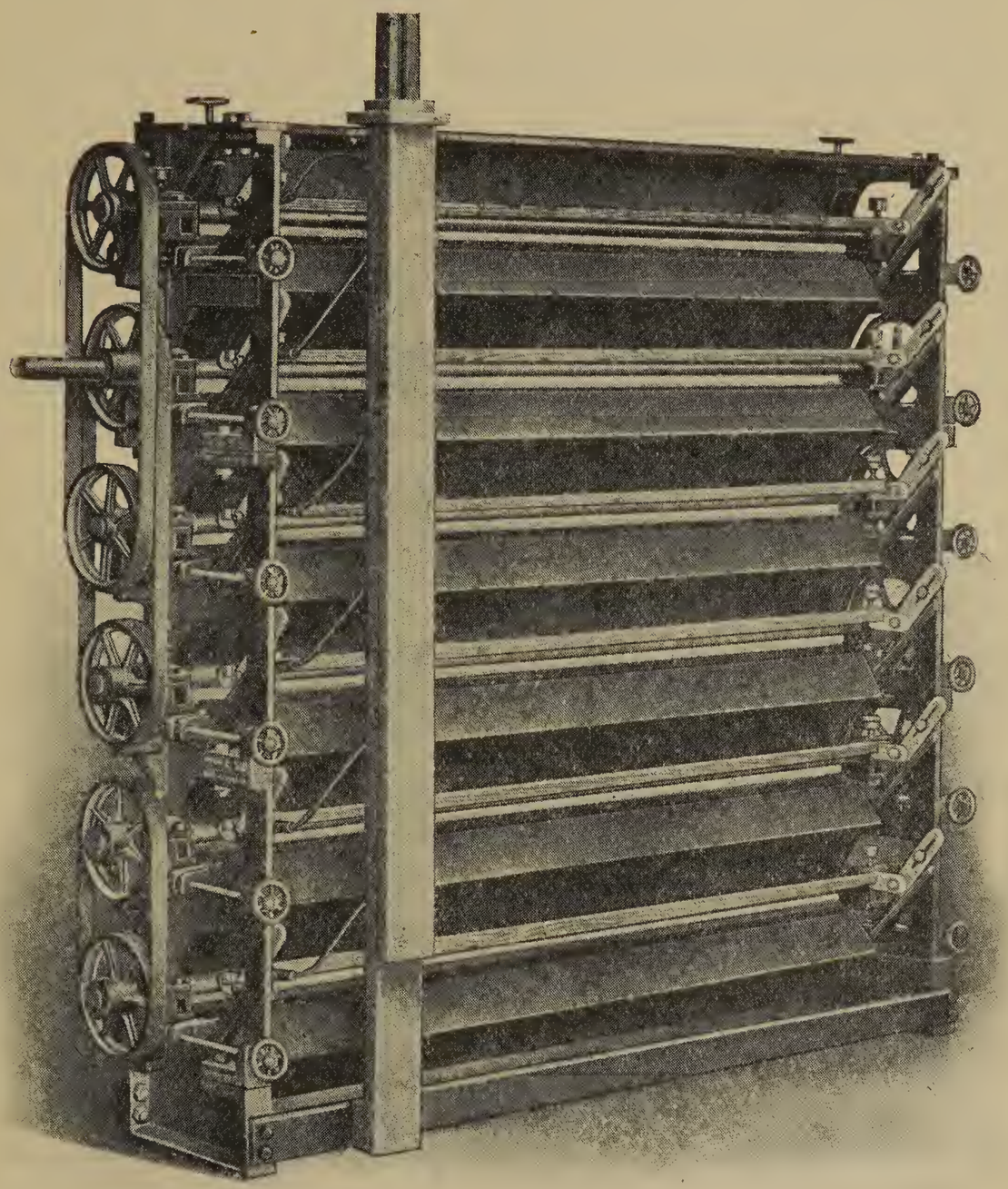


FIG. 4. Huff Electrostatic Separator.

what the grade of the feed to the mill may be (and it varies within wide limits), a fairly uniform mixture is sent to the finishing machines on the floor below.

These finishing machines give the final cleaning to the ore, one set giving a finished iron product, and the other a finished

zinc product. The middlings from these cleaners return by gravity to the boot of the elevator and mix with the fresh ore, so that no ore leaves the system that is not separated into its proper grades of product.

The finished zinc product and finished iron product fall into separate bins on the first floor. These bins are V-bottomed, and constructed of two thicknesses of wood flooring with heavy building paper between. They are elevated from the floor so that they may conveniently be drawn off into a 730-kg. (1,600-lb.) capacity push car for loading.

The car is then wheeled to a small elevator and dumped into a hopper on the floor level. This feeds the ore into the boot of a small elevator, which discharges either into a freight car by means of a goose-neck spout, or may be allowed to discharge to a second elevator in the storage bins. From these bins a car may be loaded whenever convenient.

The plant generates its own power, and the engine and boiler rooms are located in an adjoining building. The fire-boxes of the boiler and dryer are side by side, enabling the engineer to look after both fires as well as the engine room. Power is supplied by a Corliss engine, connected to the mill by a clutch.

The plant operates continuously three shifts per day. The labor required per twenty-four hours is as follows:

3 shift bosses	(8 hours each)
3 machine helpers	(8 " ")
3 dryer feeders	(8 " ")
2 loaders	(10 " ")
2 engineers	(13 and 11 hours each)

There is also a superintendent, master mechanic, assayer, one buyer and bookkeeper, although the buyer and, to a large extent, the assayer devote their time to obtaining custom work.

Two products of marketable value are obtained: The iron pyrite, hitherto valueless in these Wisconsin ores, is sold for its sulphur content, and by reason of its free-burning qualities, makes a very desirable product for the acid manufacturer; and a zinc product which is, of course, sold for spelter. The pyrite is sold by contract, but the blende is sold to the smelters on the open market. With a penalty for excess of iron or lead, one may see it is necessary for such a plant to turn out consistently

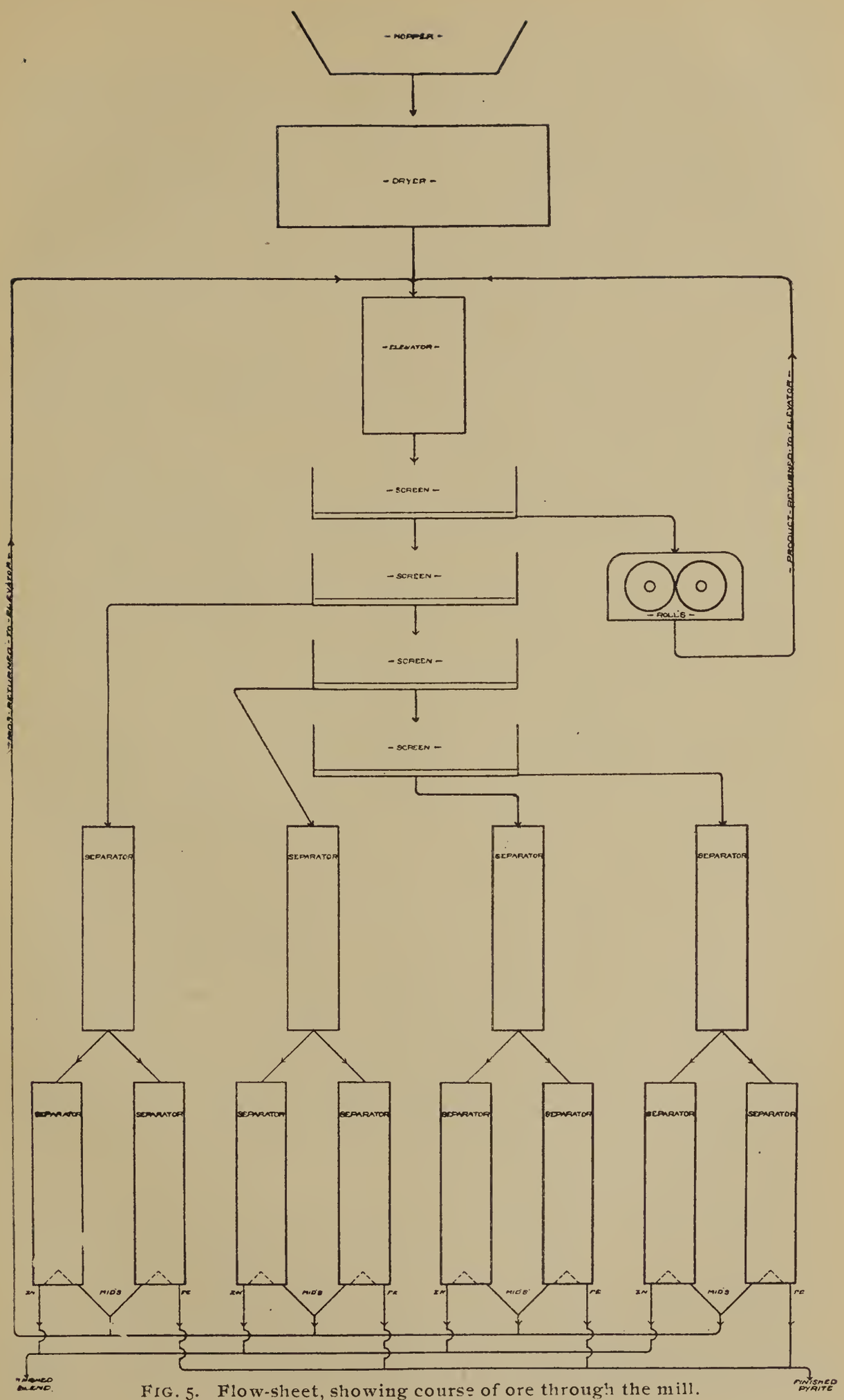


FIG. 5. Flow-sheet, showing course of ore through the mill.

high-grade products in order to command a satisfactory market price.

The results taken from the "Record of Shipments" for a month show an average zinc product of 55.2 percent Zn and 3.4 per cent Fe, and a pyrite product of 3.7 percent Zn and 44.7 percent S. The average zinc content of the ore, bought and separated into the above products, was 24.1 percent Zn, and the average iron content was 25.4 percent Fe. The minimum zinc content was 6.7 percent Zn, and the maximum 41.2 percent Zn. The high grade of the separated products shows the flexibility of the process and the ability of the plant to handle any grade of ore from the district.

As a result of the excellent showing of this electrostatic plant, the United States Smelting, Mining and Refining Company decided to put in a plant at their works at Midvale, Utah. The function of an electrostatic plant there is different from that in Platteville, for the ore from the mine of the United States company at Bingham, Utah, contains about 9 percent of zinc in addition to the gold, silver and lead values.

This ore is shipped to the concentrator at Midvale, where it is crushed and milled by the usual methods of jigs and tables. In this concentration there were formerly two products, one a lead-pyrite product carrying the iron and considerable zinc, and a tailings carrying zinc and some gold and silver values, the object being to keep the zinc as low as possible in the lead concentrate, and yet at the same time make the maximum recovery of the gold, silver, lead and copper values. The zinc added materially to the difficulty and cost of smelting the lead concentrates, and, at the same time, was a total loss. In order to recover this zinc, three products were made in the concentrator, a lead-pyrite carrying practically no zinc, tailings free from zinc, and middlings containing about 22 percent zinc, the balance pyrite and some copper, lead, gold and silver.

To treat these middlings, an electrostatic plant was built near the concentrator as shown. It is a wooden frame building, 12 x 12 meters (40 x 40 feet), and covered with corrugated sheet-iron. In general plan it is the same as the Platteville plant—finished ore bins on the ground floors, and two floors of separators. The method of handling the ore is somewhat different. The middlings

are shovelled from the table hutches in the wet concentrator into tramcars, which are pushed by hand to the platform elevator at the electrostatic plant. The cars are raised to the third floor level, and, after weighing, are dumped into a 40-ton hopper. This is built over the dryer, and feeds automatically. After drying, the ore is screened as follows: Making A size 12 on 24, B size 24 on 50, C size through 50-mesh.

The oversize is small in amount and very low in zinc, so instead of re-crushing, it is put directly into the finished pyrite. The three sizes, A, B and C, are separated, and the products drawn from the bins on the first floor into tramcars. These are run out of the mill to the loading trestle and dumped into freight cars. The pyrite product is smelted in the United States smelter nearby, and the zinc product is shipped to the Kansas zinc smelters.

The plant is electric driven by a 20 h. p. motor, the 15 Huff separators requiring about ⅓ h. p. each. The generating apparatus for the electrostatic field is located in a small room on the finishing floor. A 3 h. p. motor is direct coupled to a generator, and the strength of field is controlled from a small switchboard. The plant is operated in conjunction with the concentrator, and the superintendence, assaying and bookkeeping is taken care of by the smelter staff.

The average assays of the feed and products are as follows:

	Au. Oz. per	Ag. Ton	Cu.	Pb.	SiO_2	Fe.	Zn.	CaO
Crude ore to concentrator	0.08	3.8	0.41	8.4	28.8	14.3	9.0	6.0
Middlings to electrostatic plant	0.05	2.8	1.11	3.3	4.6	24.3	21.6	1.9
Finished pyrite	0.14	4.8	2.24	6.6	..	26.0	9.0	..
Finished blende	0.02	1.5	0.61	2.0	..	3.6	52.9	..

This electrostatic plant not only removes the objectionable zinc from the lead-pyrite concentrate, but makes of it a marketable product, and, instead of being a total loss, it is made to produce a profit. The electrostatic process in these two plants demonstrates two applications in ore dressing, one the custom plant making low-grade ores profitable, and the other as an adjunct to a wet concentrator for the recovery of zinc.

Besides these plants, there is being installed in Nevada a plant working on crude silver ores, wherein the ore goes through no concentrating machinery prior to its electrostatic treatment. The process has been proved applicable to many special problems such as the concentration of copper and lead-silver ores in heavy

gangues such as garnet, barite, epidote, etc. The accompanying table will give some idea of what can be expected with several of these problems.

The perfection of the art of electrostatic separation marks an important step in the dressing of complex or difficultly milled ores.

TABLE OF ELECTROSTATIC SEPARATIONS.

Material	Product	% Cu.	% Fe.	% Pb.	% Zn.	% SiO_2	Oz. Au.	Oz. Ag.
Low Grade Chalcopyrite in Quartz	Original . .	2.56	17.8	. .	. .	. .	0.01	2.6
	Concentrates	5.63	37.0	. .	. .	. .	0.02	5.5
	Tails	0.10	2.0	. .	. .	. .	Trace	0.4
Pyrite and Chalcopyrite in Various Gangues .	Original . .	6.37	25.0	. .	. .	. .	. . .	. . .
	Concentrates	9.33	36.3	. .	. .	. .	. . .	. . .
	Tails	0.14	1.9	. .	. .	. .	. .	. . .
Chalcopyrite and Bornite in Garnet	Original . .	3.60	18.6	. .	. .	32.3	(Iron partly in Sulphide and partly in Garnet.)	
	Concentrates	19.10	25.7	. .	. .	14.4		
	Tails	0.34	17.6	. .	. .	36.7		
Zinc, Iron, and Silver Ore . .	Original . .	2.61	23.8	13.9	19.4	. .	. . .	52.8
	Concentrates	3.33	30.7	16.4	6.4	. .	. . .	69.0
	Tails	0.91	3.4	2.7	51.8	. .	. . .	4.6
Zinc, Lead, and Iron Middlings,	Original . .	. .	20.2	12.6	23.1	5.2	. . .	. . .
	Concentrates	. . .	31.2	21.0	4.0	3.2	. . .	. . .
	Tails	. .	2.4	0.5	53.8	8.5	. . .	. . .

Material	Product	% Cu.	% Fe.	% Pb.	% Zn.	% S.	% SiO_2
New Mexico Concentrates . . .	Original .	2.11	16.2	. . .	29.9	. . .	12.9
	Concentrates	5.65	37.2	. . .	4.9	. . .	6.6
	Tails	0.13	4.2	.	44.9	. . .	15.9
Zinc from Above Tailings . . .	Original . .		. . .	.	. . .	. . .	. . .
	Concentrates	. . .	. . .	. . .	57.1	. . .	. . .
	Tails . .	.	. . .	. . .	1.3	. . .	. . .
Native Copper in Sandstone . .	Original . .	2.68	. . .	. . .	. . .	. . .	. . .
	Concentrates	38.70	. . .	. . .	. . .	. . .	. . .
	Tails	0.27	. .	. . .	. . .	. . .	. . .
Pyrite Concentration for Sulphur	Original . .	. . .	. . .	. . .	. . .	30.1	. . .
	Concentrates	. . .	. . .	. . .	. . .	44.8	. . .
	Tails .	. . .	. .	. .	. . .	3.0	. . .
Middlings from Joplin, Mo. . .	Original .	. . .	10.8	2.5	49.5	. . .	. . .
	Concentrates	. . .	37.4	9.9	2.9	. . .	. . .
	Tails	. . .	1.6	Trace	62.3	. . .	. . .

DISCUSSION.

PROF. J. W. RICHARDS: I think Mr. MacGregor should be congratulated on the very successful results attained with a very difficult material.

It may not be known to most of you that zinc occurring in lead ore is such an undesirable constituent that lead smelters put a penalty on it when the proportion of zinc is over a certain amount. There is really more zinc mined in lead ore than is obtained from pure zinc ore in the zinc works of the United States, so that we are really wasting more zinc in order to get the lead than we are producing zinc. A man who invents a process by which we can take a harmful ingredient, on which a penalty is put for its presence, and separates it so that both metals can be utilized, is certainly doing great benefit to the country at large.

MR. ———: What is the daily output of the machine?

MR. F. S. MACGREGOR: The capacity of a machine is hard to determine because it depends upon the character of the ore and on the size of the particles, so that the only way we can get at the capacity is to take the mill as a whole; that is, there are 15 machines in a plant and it has an output of 60 tons a day, while at the Platteville plant we have 15 machines which are running and give an output of 75 tons a day, which is just the difference in the character of the ores.

MR. LLOYD: I am not sure whether I understand correctly: Is the voltage first transformed to 24,000 volts and then rectified mechanically by a connection of the generator shaft?

MR. MACGREGOR: Yes.

A paper presented at the Eighteenth General Meeting of the American Electrochemical Society, in Chicago, Ill., October 14, 1910, President Wm. H. Walker in the Chair.

NOTES ON TRIBO-LUMINESCENCE

By W. S. Andrews.

The term "Luminescence" has been applied to the light which is emitted by various substances at a temperature much lower than that which is neccessary to show visible incandescence, as illustrated for example in the light of the fire fly, decaying wood, and many natural and artificial mineral compounds.

The general phenomenon of luminescence has been divided into several classes by Dr. Sylvanus P. Thompson, as shown in the following tabulation which is copied from his book entitled "Light Visible and Invisible," page 175, (1893).

Phenomenon.	Substance in which it occurs
1. Chemi-luminescence	Phosphorus oxidising in moist air; decaying wood; decaying fish; glow-worm; firefly; marine organisms, etc.
2. Photo-luminescence	
(a) transient: Fluorescence	Fluor-spar; uranium-glass; quinine; scheelite; platino-cyanides of various bases; eosin and many coal-tar products.
(b) persistent: Phosphorescence	Bologna-stone; Canton's phosphorus and other sulphides of alkaline earths; some diamonds, etc.
3. Thermo-luminescence	Fluor-spar; scheelite.
4. Tribo-luminescence	Diamonds; sugar; quartz; uranyl nitrate; pentadecyl-paratolylketone.
5. Electro-luminescence	
(a) Effluvio-luminescence	Many rarefied gases; many of the fluorescent and phosphorescent bodies.
(b) Kathodo-luminescence	Rubies; glass; diamonds; many gems and minerals.
6. Crystallo-luminescence	Arsenious acid.
7. Lyo-luminescence	Sub-chlorides of alkali metals.
8. X-luminescence	Platino-cyanides; scheelite, etc.

Tribo-luminescence, to which the present remarks particularly refer, is the property possessed by certain bodies of emitting light when rubbed or scratched.

A number of natural minerals exhibit different degrees of this property, an interesting investigation of which is described in a paper by Mr. Wallace Goold Levison, published in Science, N. S. Vol. XIX, No. 491, pp. 826, 827.

A simple but rather faint illustration of the phenomenon may be easily produced by rubbing together two lumps of white sugar in the dark.

While experimenting in the production of fluorescent and phosphorescent materials several years ago, the writer accidentally discovered that one of his preparations exhibited tribo-luminescent properties, and two or three subsequent trials led to improved results. As an easily prepared artificial product of this kind does not appear to be generally known, some brief directions for making it may be of possible interest.

The following mixture was selected as the best after a series of experiments.

Zinc carbonate (C. P.)	70 parts by wgt.
Flour sulfur	30 " " "
Manganese sulfate	trace

The zinc carbonate in fine powder should first be mixed with the flour sulfur. Then a small particle of manganese sulfate should be dissolved in distilled water and enough of the solution added to the powdered materials to make a thick cream. After being thoroughly triturated in a mortar, the mixture can be poured into a shallow glass or earthenware dish and allowed to dry at a gentle heat. When quite dry it should be again reduced to a fine powder, and packed *hard* into a porcelain or Battersea crucible with a tight cover, and subjected to a bright red heat for twenty minutes. The mixture shrinks considerably and cinters together into a stone-like mass, which possesses the peculiar property of tribo-luminescence to a marked degree, so that when scratched with a knife blade or sharp point, it emits a train of minute sparks showing a yellowish light. This light appears to have little or no heating effect as it will not ignite any inflammable vapor or gas, so that in this regard, it differs essen-

tially from the light and sparks produced by striking together flint and steel, or the scratching of a pyrophoric alloy of iron and cerium.

DISCUSSION.

Mr. F. C. Frary: I would like to ask if this is the same phenomenon which everybody has noticed when they tear off the little piece of glued cloth which attaches the films of the Eastman film-pack to the paper tabs; we always get a phosphorescence there; is it due to tribo-luminescence, or is it an electrical phenomenon?

Mr. Richards: I have a sample of the material which was sent by Mr. Andrews, and it is a rather compact, hard material. I am not sure that the luminescence can be seen in this light, but when it is rubbed with steel it leaves a faintly luminous path over the place where it was rubbed. It looks like the head of a phosphorous match that has been rubbed. The luminescence appears to be the result of the friction of the steel against the material. I have not been able to observe sparks. I am not sure that a chemical investigation of the product has been made to see just what compounds are in the material. It seems possible that the sulphur would convert the zinc carbonate into zinc sulphide.

Mr. Seede: I think that sphalerite and willemite have the same property.

A paper read at the Eighteenth General Meeting of the American Electrochemical Society in Chicago, Ill., October 15, 1910; President Wm. H. Walker in the Chair.

THE UNIT CHARGE IN GASEOUS IONIZATION.

By Robert A. Millikan.

Electrochemists have discussed "ions" almost *ad infinitum,* and will therefore be interested in a physicist's determination of the actual, quantitative value of the unit, ionic charge. The writer has devised a method by which the unit charges existing in an "ionized" gas may be isolated and their amounts determined quantitatively with a considerable degree of accuracy. It must be borne in mind that the unit of charge thus determined is that existing upon the ions of atmospheric air either when it is in its natural condition, or when it is subjected to ionization from any of the usual ionizing agents, like x-rays or radium. However, since it has been conclusively shown by three independent observers that the product Ne, where N is the number of molecules in a gram molecule and e the charge carried by a univalent ion in electrolysis, is identical with the product Ne in gaseous ionization, where e now represents the average charge on the negative ion in such ionization and N has the same significance as before, it will be evident that it is pretty well established that the charge carried by the univalent ion in electrolysis is identical with the charge here measured.

The full description of the apparatus and the method used may be found in a paper read before the American Physical Society, April 23, 1910; and published in *Science,* September 30, 1910. The following description will present the matter in a way which I trust will be easily comprehensible to the electrochemist.

A cloud of fine drops of oil, or of mercury or of some other very slightly volatile liquid is produced by an atomizer, and carried by the air blast above a brass plate in which is a pin hole. The blast being shut off, a fine mist falls through the hole into the stagnent air space beneath. Below this plate is another, held at a distance of 16 mm. from the first by ebonite insulating posts.

A telescope is mounted so as to observe the drops as they float down under the influence of gravity from the pin-hole, being illuminated meanwhile by a strong beam of light. The small drops appear in the field like brilliant stars of varying magnitudes. The micro-telescope has two horizontal cross hairs for timing the rate of descent of the drops. According to Stokes law, a drop of this sort falls with a velocity which is directly proportional to g, the gravitational constant, to the square of the radius of the drop, a^2, to the difference in density between the drop and the medium in which it falls, and inversely proportional to the coefficient of viscosity, u, of the medium. The numerical relation is

$$v_1 = \frac{2}{9} \frac{g\ a^2}{u} (d^1 - d)$$

If the rate of fall across the field from one cross hair to the other under the influence of gravity alone is determined, it is possible to calculate with the aid of the above equation the radius and thence the mass of the individual drops.

Arrangements are provided by which the two plates may be electrically charged to a potential of 3,000 to 10,000 volts, and by a simple switch movement the polarity may be reversed, or the potential thrown off and the plates short-circuited.

When a freely falling globule is under observation, if, as is usually the case, it has already received a charge in the atomizing process, it is observed that as soon as the field is thrown on between the plates, the globule changes its velocity, either falling more quickly or more slowly, or standing still, or even rising against gravity. A drop of the last mentioned sort is selected for observation, and its speed down under gravity, then its speed up under the influence of the electrical field, are measured with an almost unlimited degree of accuracy, since the operation can be repeated an indefinite number of times or until the drop catches one or more of the ions which exist normally in atmospheric air or which are produced in it by any of the familiar ionizing agents. As soon as this happens, the speed of the drop under the influence of the electrical field changes instantly. If the charge caught is of opposite sign to the charge already on the globule, the latter has its upward velocity diminished; if the charge caught is of the same sign as that on the globule, the upward velocity is

increased. While such a globule is rising, its direction may be at once reversed by reversing the charges on the plates, for when rising, it moves under the action of the electric force minus gravity; when falling, under the influence of the electric force plus gravity.

By carefully timed observations of the velocities, first under gravity, then under the influence of the field, it is easy to obtain the values of the successive charges carried by a given drop after the capture of a larger or smaller number of ions. The difference between any two such successive values is obviously the charge carried by the captured ion. Thus, if v_1 is the speed with which the drop moves under the influence of gravity, and v_2 its speed under the electrical pull of a field of intensity F, then m being the mass of the drop, and g the gravity constant, the charge on the drop, e_n, in terms of mg must be given by

$$e_n = \frac{m\,g}{Fv_1}\,(v_1 + v_2)$$

This equation involves no assumptions except that the speed of the drop in the resisting medium is proportional to the force acting on it, an assumption which has been experimentally proved to be correct in the course of this work.

Experimental Results.

In one series of carefully timed observations the different electrical charges carried by the oil drop throughout a period of 4½ hours in ordinary air were found to be as follows, the unit of measurement being the absolute electrostatic units $\times\ 10^{10}$.

19.66	53.92
24.60	59.12
29.62	63.68
34.47	68.65
39.38	78.34
44.42	83.22
49.41	

The inspection of these figures shows a nearly constant difference, the successive differences being

4.94	4.51
5.02	5.20
4.85	4.56
4.91	4.97
5.04	2(4.70)
4.99	4.88

This observation seems to show that the charges acquired by the drops are either always of the same value or else simple multiples of that value; furthermore, that the charge originally upon the drop consisted in this case of four of these unit charges is shown by the fact that $19.66 \div 4 = 4.915$.

The explanation of all of these phenomena is therefore similar to that of Dalton's chemical law of simple multiple proportions; the charges taken up by the globules and measured in the above tests are simply multiples of the primitive ionic charge existing in the gas. The accuracy with which they are multiples in this experiment may be shown by dividing the observed charges by an average value for the unit charge deduced from a careful comparison of the data, viz., $e = 4.917 \times 10^{10}$.

The simple multiple proportions of the charges then become:

19.66	÷	4.917	= 3.998	53.92	÷	4.917	= 10.966
24.60	÷	"	= 5.003	59.12	÷	"	= 12.025
29.62	÷	"	= 6.024	63.68	÷	"	= 12.971
34.47	÷	"	= 7.011	68.65	÷	"	= 13.962
39.38	÷	"	= 8.009	78.34	÷	"	= 15.932
44.42	÷	"	= 9.034	83.22	÷	"	= 16.925
49.41	÷	"	= 10.049				

Continued observations of greater accuracy showed that Stokes' law does not hold for extremely small drops approaching molecular dimensions, and a modified form of Stokes' law was determined. The final result of all the tests gives $e = 4.90 \times 10^{10}$, as the absolute electrostatic unit charge; this is believed to be accurate to 0.5 percent.

Evidence of valency in the ionized gas was observed, since the globules gained at times 1, 2 or 3 unit charges at once, apparently by contact with a 1, 2 or 3 valent ion.

The investigation has proved that electricity is, so to speak, *atomic* in structure; that an electrical charge, instead of being spread uniformly over a charged surface, has a definite granular structure; that the kinetic theory of gases agrees in its fundamentals with the facts disclosed; and that the phenomena of valency are exhibited to some extent in gaseous ionization. Moreover, it has fixed the unit of electrical charge, the "atom of electricity," at 4.90×10^{-10} absolute electrostatic units of quantity, or 1.63×10^{-19} coulombs.

DISCUSSION.

DR. RICHARDS: I would like to ask Professor Millikan whether he has used other gases than air, and if they would give any different result?

PROF. ROBERT A. MILLIKAN: Well, we are at that now. No, these experiments were all made in air, because theoretically it doesn't make any difference what the medium is. Of course, other media should furnish an interesting check upon the result obtained in air. It takes a good while to get such a series of observations.

DR. RICHARDS: Might not the ionization be different in the other cases?

PROF. MILLIKAN: Yes, it might, but the charge on each ion is not likely to be different.

A MEMBER: I wish to second the remark of the Chairman in calling attention to the importance of this work. I have at this time only one question to ask, and that is in regard to the work of Ehrenhaft in Vienna, who calculated the unit charge, and I believe some of his values were smaller than the ordinary unit charge. I would like to have Professor Millikan to be so kind as to give his interpretation of Mr. Ehrenhaft's result, especially with a view of whether Stokes' law applies to it. I believe they are considerably smaller.

PROF. MILLIKAN: Ehrenhaft doesn't know what the trouble is. He concludes either that there isn't an elementary charge, or that it is much smaller than the value here obtained, or else that Stokes' law is not true. These results show that the last alternative is the correct one. His particles are something like one-tenth the size of these particles. I think there are three reasons why Stokes' law breaks down for such particles; one I have already given; another is that when the drop becomes sufficiently small, the apparent viscosity of the medium is affected by the charge on the drop. I mean to say that the electrical charge pulls in more molecules. This effect doesn't appear in our experiment because the drops are so big. The third cause of failure of Stokes' law arises from the Brownian movements. In a word, Ehrenhaft's troubles all arise from the fact that he assumes Stokes' law.

THE CHAIRMAN: The University of Chicago can certainly feel very proud for this wonderful piece of work going on in its laboratory. Prof. Millikan has his apparatus in working order, in the physical laboratory, and will be pleased to show the actual operation to any who will now accompany him there.

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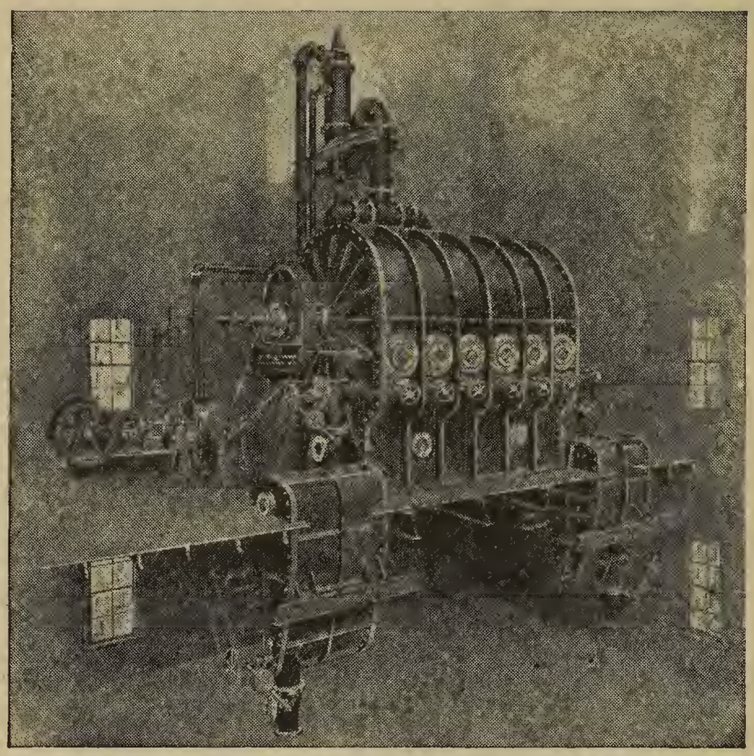

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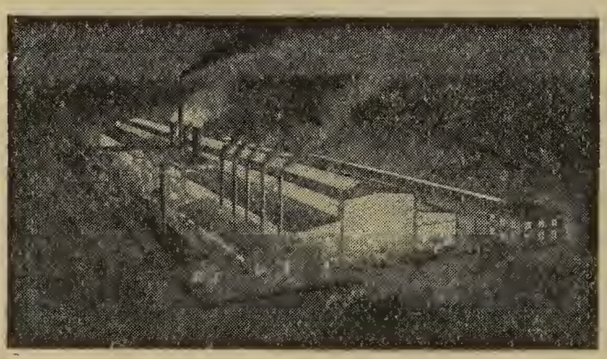

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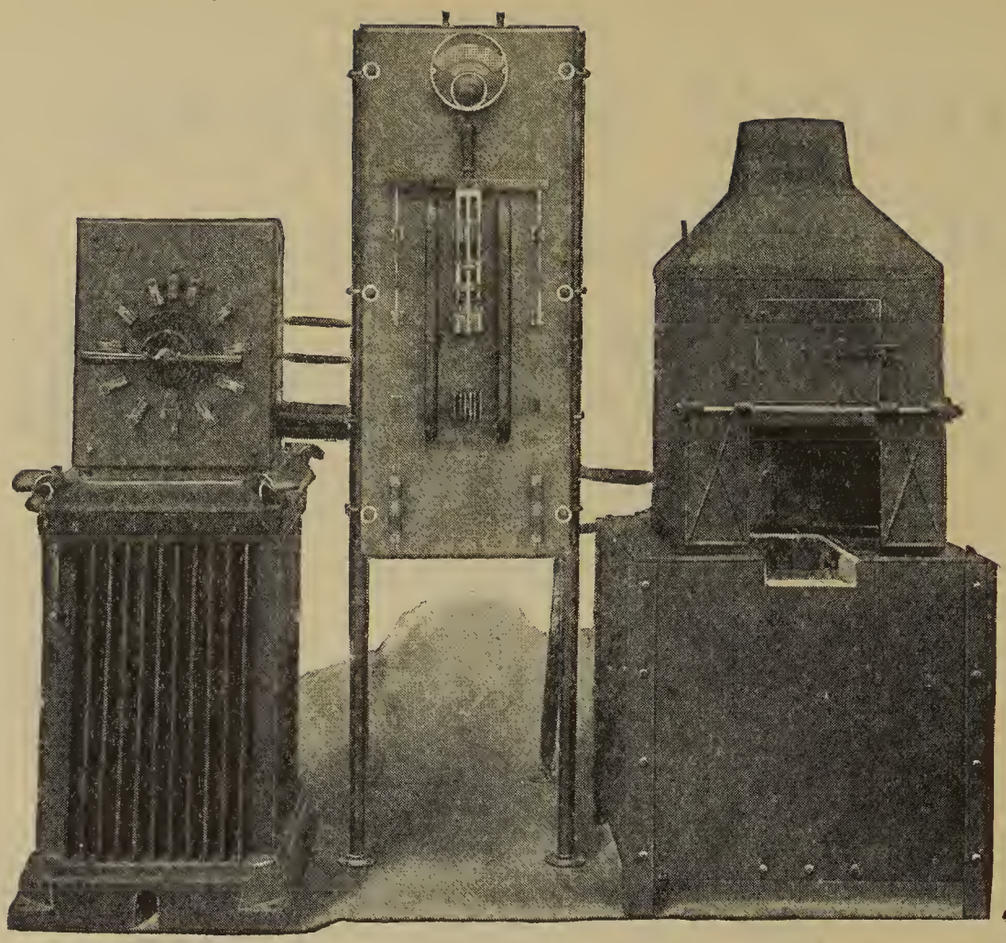

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